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A

COMPENDIUM

OF A

COURSE OF LECTURES

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1-5.

ON

NATURAL AND EXPERIMENTAL *PHILOSOPHY.*

VIZ.

PROPERTIES OF MATTER AND MAGNETISM.
CHEMISTRY. ELECTRICITY.
HYDROSTATICS. FORTIFICATION.
HYDRAULICS. MECHANICS.
OPTICS. ASTRONOMY, &c.

> With thee, ſerene Philoſophy, with thee
> We ſpring aloſt with elevated pride
> Above the tangling maſs of low deſires,
> That bind the flutt'ring croud; and, angel-wing'd,
> The height of ſcience and of virtue gain,
> Where all is calm and clear. THOMPSON.

TO WHICH ARE ADDED

NOTES AND DEMONSTRATIONS,
POETICAL EXTRACTS, &c.

By I. ATKINSON. k

KENDAL:
PRINTED FOR THE AUTHOR, BY JAMES ASHBURNER.
MDCCLXXXIV.

SEVERAL *ſubſcribers to this courſe having intimated their deſire of having an abſtract of the lectures, to aſſiſt them in the recollection of ſuch parts as they might wiſh to remember, but which could not poſſibly be treaſured up in the memory at the time of delivery, the following Compendium is drawn up for their uſe; and a number of Notes are added, to explain and demonſtrate ſuch rules as the young ſtudent in philoſophy might not, perhaps, without ſome ſuch help, have perfectly underſtood; an addition which, it is hoped, by making the matter more intelligible, will render it more agreeable.*

COMPENDIUM

OF A

Courſe of Lectures,

ON

Natural and Experimental PHILOSOPHY.

LECTURE I.

PROPERTIES OF MATTER AND MAGNETISM.

THE deſign of theſe lectures is to deliver, in a conciſe manner, the principles of Natural Philoſophy, according to the great Sir Iſaac Newton, and as free as poſſible from the mathematical elements; becauſe demonſtration after a rigorous and geometrical way would probably be unintelligible to ſome of my ſubſcribers, and therefore, to be better underſtood, I will endeavour to expreſs myſelf upon the ſubject in a manner ſuitable to all capacities.

Def. 1. NATURAL Philoſophy is a ſcience which gives the cauſe and reaſon of thoſe effects and changes which are obſerved to happen among the natural bodies of this world.

Def. 2. By a natural body of this world is meant any diſtinct aſſemblage of matter, whether ſolid or fluid; therefore all the bodies of this world comprize the whole ſyſtem of matter which it contains. But neither theſe bodies, nor thoſe parts of matter, are ſo fixed and determined to any one abſolute place or ſituation, but that they may be removed to another.

Def. 3. When we obſerve any of theſe changes produced, the appearance of ſuch change we call *Natural Phænomena*, and the reaſon of natural phænomena it is the buſineſs of natural philoſophy to explain; and this is no ſmall branch of learning, for it both importantly regards the common affairs of life and is alſo a high and refined part of ſpeculative knowledge, no leſs than a view into the laws which Providence hath appointed for the regulation of all things; and upon this account, if it terminated in ſpeculation only, it would neither be an uſeful nor an entertaining ſcience. To be gratified with a view of the methods which nature makes uſe of in her works, and to ſee the perfect chain of reaſon maintained in the conſtitution and deſign of things, muſt give the higheſt ſatisfaction to a rational mind; for to admire a thing before it be underſtood is the paſſion of a light mind, but when the nature of the thing is laid open, when all the arguments and adjuſtments become known, and ſeen to be exquiſitely modeled, it will ſtrike a man of underſtanding with admiration. It is true there is a beauty and harmony in the works of nature which cannot eſcape the moſt vulgar eye; the viciſſitudes of ſeaſons, the alternate revolution of day and night, the profuſe gaiety of the fields, the artleſs melody of the inhabitants of the woods, and a thouſand other pleaſing varieties, will always charm the mind of every intelligent and reflecting being; yet the rapture is infinitely improved to a mind that can trace all theſe effects to their cauſes, and take the whole mechaniſm of nature under proper examination. The advantages of natural philoſophy accrue not only to ſpeculative men, they greatly affect all mechanics; the perfection of engines, inſtruments, and machines, for carrying on the affairs of ſociety, entirely depending on a thorough knowledge of the laws of nature.

Sir Iſaac Newton in his *Principia* has laid down the four following rules, as the fundamental principles to be obſerved in our purſuits after philoſophical knowledge.

Rule 1. More cauſes of natural things are not to be admitted than are both true and ſufficient to explain the phænomena.*

Rule 2. And therefore of natural effects of the ſame kind, the ſame cauſes are to be aſſigned, as far as it can be done.†

Rule 3. The qualities of natural bodies which cannot be increaſed or diminiſhed, and agrees to all bodies in which experiments can be made, are to be reckoned as the qualities of all bodies whatſoever.‡

Rule 4. In experimental philoſophy propoſitions collected from the phænomena by induction are to be deemed either exactly or very nearly true, till other phænomena occur, by which they may be rendered either more accurate, or leſs liable to exceptions.§

If according to theſe rules we take a ſurvey of the viſible world, and ſtrictly examine the nature of particular bodies, we ſhall find reaſon to conclude that they all conſiſt of one and the ſame ſort of matter, and that all the diverſity or difference ariſes only from the various modifications and different adheſions of the ſame particles of matter.

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* For nature does nothing in vain, but is ſimple, and delights not in ſuperfluous cauſes of things.

† As the reſpiration of man and beaſts; of light in a culinary fire and in the ſun, &c.

‡ Thus becauſe hardneſs, diviſibility, gravity, &c. are found in all bodies which fall under our inſpection, we may juſtly conclude they belong to all bodies whatſoever; and are therefore to be eſteemed the original and univerſal properties of all natural bodies.

§ This ought to be done, leſt arguments of induction ſhould be deſtroyed by hypotheſis.

Matter thus variouſly configurated conſtitutes an infinite variety of bodies, which are found to have the following properties, *viz.*

Extension, or that by which it poſſeſſes, or takes up, ſome part of univerſal ſpace; which ſpace is called the ſpace of that body.‖

Solidity, ſometimes called the impenetrability of matter, is that property by which a body excludes all others from the place which itſelf poſſeſſeth; for it would be abſurd to ſuppoſe that two bodies could poſſeſs one and the ſame place at the ſame time.

Divisibility, is that property by which the particles of matter in all bodies are capable of a ſeparation or diſunion from each other: how far this may actually obtain in nature is not eaſy to ſay, but in a mathematical conſideration is demonſtrable various ways.‡

‖ All bodies are extended, 1. into length only, which is called a *line*; 2. into length and breadth, which is called a *ſuperficies*; 3. into length, breadth, and depth, which is called a *ſolid*. Theſe are the three dimenſions, according to the quantity of which the magnitude or bulk of bodies are eſtimated. Lines are in the ſingle ratio, ſuperficies are in the duplicate ratio, and ſolids are in the triplicate ratio.

Single ratio, 3 : 4 :: 6 : 8
Duplicate ratio, 4 : 9 :: 16 : 36
Triplicate ratio, 1 : 8 :: 8 : 64

‡ If a pound of ſilver be melted with a ſingle grain of gold in it, the gold will be equally diffuſed throughout the whole.

A grain of gold can be extended by goldbeaters into a leaf of fifty ſquare inches, and this leaf may be divided into 500000 viſible parts; (for an inch in length can be divided into 100 parts) then if one of theſe parts be magnified by a microſcope that magnifies 100 times it will make 10000, and that number multiplied by 500000, will produce 5000 mil. and prove that this aſtoniſhingly ſmall part of a grain of gold can be made viſible. Such leaves are uſed in gilding, and if 124500 were laid together they would be only one inch thick.

MOBILITY is that property which all bodies have of being moveable, or capable of changing their places: this property is evident to all our ſenſes.

THE *Vis Inertia*, or inactivity of matter, is that property by which it endeavours to continue in its ſtate of motion or reſt; or by which it reſiſts the actions or impreſſions of all other bodies which tend to generate or deſtroy motion therein.*

ATTRACTION is a property that we find all matter endued with in a greater or leſs degree: by this property the particles of matter attract each other by a power that cauſes them mutually to accede to each other. This tendency of one body to another is called *gravitation*, or in the abſtract *gravity*.

REPULSION ſeems to be a property belonging to the ſmall particles of matter univerſally; for they do not more evidently attract in ſome circumſtances than they repel in others.

Theſe are the general properties of matter, which we muſt regard in our explications of the various phænomena of nature in the ſenſe we have defined them; they are the ſeveral *data*, or fundamental principles, on which the ſcience of philoſophy depends, and will each of them afford an ample field both in the ſpeculative and practical parts. I ſhall begin with the attraction of bodies, conſider its ſeveral ſpecies, and prove their exiſtence, and the properties of each, by experiments.

THE power of attraction, or cauſe of gravity, cannot be preciſely defined, but that ſuch a power does exiſt is evident, and the laws of its action I ſhall aſſign by reaſon and experiment.

To this end we muſt conſider, that any kind of power, proceeding from a body in right lines every way as from a center, muſt decreaſe in ſtrength as the ſquare of the diſtance from the body increaſes.[†] Hence light, heat, odours and perfumes, which conſiſt of particles or effluvia, that proceed every way from luminous, heated, and odoriferous bodies, as from a centre, have always their forces abated according to the above law. The force of ſound alſo decreaſes in the ſame proportion.

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* Matter can neither move nor ſtop of itſelf,—proved by a ball upon the whirling table, which neither begins to move when the table moves, nor ſtops when the table ſtops.

By virtue of this attracting power the grand machinery of the ſolar ſyſtem is governed; it is therefore of the greateſt conſequence to be acquainted with the different ſpecies of this univerſal power, and to learn by experiment the peculiar nature, laws, or manner of action in each ſort of attraction, which are reckoned four, *viz.* Coheſion, Electricity, Magnetiſm, and Gravitation. I ſhall only explain the attraction of coheſion and the attraction of magnetiſm in this lecture, as the attraction of electricity will be explained in lecture 6th, and the attraction of gravitation in lecture 7th.

THE Attraction of Coheſion is diſcernible in the ſmalleſt particles of matter; for thoſe particles mutually attract, and are attracted by each other.[‖]

THE ſphere of attraction, or extent of this power, is greater in ſome particles of matter than in others, but very ſmall at the utmoſt;[‡] and is inſenſible in ſolid bodies at the leaſt ſenſible diſtance, acting as it were only by contact: conſequently, it muſt be nearly proportional to the quantity of contiguous ſurface, or the parts cohere moſt ſtrongly whoſe touching ſurfaces are largeſt.

[†] IF three pieces of wood, in form of a pyramid, are ſet end to end, the firſt is as one, the ſecond is as four, and the third is as nine; for ſuppoſe a body one ſemidiameter of the earth's diſtance from its centre, which upon its ſurface weighs 36 ℔. at twice that diſtance it will weigh only 9 ℔.

For $1 \times 1 = 1$, and $\frac{36}{1} = 36$ ℔
For $2 \times 2 = 4$, and $\frac{36}{4} = 9$ ℔
For $3 \times 3 = 9$, and $\frac{36}{9} = 4$ ℔

[‖] PROVED by water riſing by the ſide of a glaſs—for the particles of glaſs have a greater attracting power than the particles of water—By capillary tubes, lead balls, glaſs planes, &c.

[‡] PROVED by water riſing above the common level in capillary tubes, and mercury ſinking below it. By water adhering to common ſubſtances, which mercury leaves dry,—for the particles of mercury have a greater attraction than the particles of water, &c.

THIS power decreaſes in force as the ſquare of the diſtance increaſes.

WHERE the ſphere of attraction ends, a repelling power begins, by which the particles, inſtead of attracting, repel and fly off from each other.* By this power the ſmall portions of a fluid make a ſpherical figure.†

THE *Rationale* of ſeveral important particulars hereafter mentioned will eaſily appear from the preceding principles or properties of matter.

HARDNESS and FIXITY are owing to the ſame cauſe, and are oppoſed to fluidity. The hardneſs of bodies ariſes from ſuch figures of the particles of matter as permit them to touch by large ſurfaces, and thus to have a greater power of attraction, and ſo fall and fit into one another that they prevent any motion among themſelves by any external preſſure: whereas in fluids they yield to the leaſt preſſure, and therefore the attractive power, by which the particles of a fluid cohere, muſt be the leaſt poſſible, ariſing from their ſpherical figure,

ELASTICITY ariſes from the ſame principle of corpuſcular attraction; for if a ſteel ſpring, wire, &c. be bent out of its natural poſition, the particles on the convex ſide are forced from that intimate contact they had before, and on the concave part are forced nearer together; in both caſes there is a great reſiſtance to be overcome, which requires a ſuperior force. During this ſtate the particles are under a ſort of tenſion on one ſide and compreſion on the other; and ſince by this force they are not drawn out of each others attraction, as ſoon as the force is remitted, or ceaſes to act, the attractive power reduces the particles, unbends the wire, and reſtores it to its natural ſtate.

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* **EVIDENT** between fat and water; alſo by the aſcent of ſteam or vapour from humid and fluid bodies, and by the *Eolopile*.

† **PROVED** by forcing quickſilver through leather that is divided into ſmall portions, which always form themſelves into a ſpherical figure.

Soldering is another effect of this coheſive power; for when the ſurfaces of two pieces of metal are made clean, and the ſolder fluxed, its particles will freely enter the pores, and by that means adhere firmly to each other. Cement and Glue are of the ſame kind, but differ in degree of coheſive power. †

Foliating glaſs depends upon the ſame principle; for when the foil and quickſilver unite, and the glaſs put upon it, the glaſs attracts the foil, and they form one body.

Melting or fuſion of fixed bodies depends upon the ſame theory; for when the particles of a fixed body are ſeparated by the action of heat, ſo far as to be almoſt out of each others attraction, they will then move eaſily by each other, and put on the appearance of a fluid body.

The philoſophers are at a loſs to find the true cauſe of heat and cold, nor are there any who can give a juſt and perfect account of them. The effects are theſe; heat has a retraction towards its own body, but an attraction to others: it is generally ſuppoſed that it acts upon bodies by the friction of ſome fluid ſubſtance or matter; for all things are expanded by heat and retracted by cold, as it is certain they act contrary to each other.§

Water is longer of heating and cooling than any other ſubſtance or metal: why it is ſo cannot eaſily be accounted for.[‡]

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† Leather that is prepared with bark will not diſſolve ſo as to form glue; conſequently the leather muſt be prepared with allum.

§ If a phial be partly filled with ſpirits of wine and immerſed in hot water, the ſpirit will gradually riſe till it reaches the top, but immediately put into cold water it will return to its natural ſtate. Alſo, if a pair of ſcales whoſe bottoms are equal have one of them heated, it will be conſiderably lighter than the other;——which proves, that heat by expanding bodies does not make them ponderous, neither does froſt by expanding add weight according to bulk, for ice is lighter than water.

Snow and ice contain a great quantity of heat.[‖]

Water does not boil at the vaporific point all at once, only part of it at a time; and ſo by degrees becomes all in a vaporific ſtate; but if the ebullition ſhould ſuddenly take place, ſo as to be diffuſed over the whole of it, it might be of the moſt dangerous conſequence, from its exploſion like gunpowder.

If a phial filled with water be dipped into a veſſel of ether an evaporaion will at firſt be promoted; but by dipping it in two or three times it will congeal, and be formed into ice.[†]

Heat is one of the greateſt phænomena of life. It would be impoſſible for us to live without heat; for if it was always cold without any degree of heat, the water would become one ſolid maſs like a ſtone, and the air become congealed in a ſimilar manner: on the other hand, if there was no cold, but a continual ſummer, every thing would become putrid, the water would be in a vaporific ſtate, and be very offenſive; and the air become one ſolid maſs, and fall ponderous on the ground. We therefore conclude that both heat and cold are highly neceſſary for our ſupport and exiſtence.

Evaporation—Fire, heat, or rarefaction, by which watery vapours are ſuppoſed to become ſuperficially lighter than air, are found to be the only cauſe of their aſcent into the atmoſphere. If heat be the only cauſe of evaporation, water in a warm room would evaporate faſter than when in a cold place, where there is a conſtant current of air;—which is contrary to experience. The evaporation of water is ſo far from depending on its being rarefied by heat, that its carried on even whilſt water is condenſed by cold;* and as the ſuſpenſion of the particles of water in air, of ſalt in the waters of the ocean, &c. ſeems to be phænomena of the ſame kind, we may reaſonably ſuppoſe that they ariſe from the ſame cauſe, and that what we call evaporation is nothing more than a gradual ſolution of water into air.‡

[‡] Take equal quantities of water and quickſilver, heat the quickſilver, pour it into the water, and it will cauſe a ſmall degree of heat in the water; but if you pour as much hot water upon the water it heats it more. From this we may obſerve, that the quickſilver, from its denſity, contains its heat more within it; the other being a more fluid ſubſtance diffuſes its heat to air or water.

[‖] Mix ſnow with ſome nitrous ſalt, the ſnow will be colder by 32° below Faranheit's ſcale; but immerſe the thermometer in ſnow and it will aſcend according to the degree of heat to which it is expoſed.

By boiling water, then expoſing it to the air, and adding ſome nitrous ſalt to it, we obtain ice.

[†] Cover the bottle with muſlin, put a cork into it, and tie a ſtring round it; it may be hung in the air, and as the muſlin dries may be repeatedly dipt in the ether.

When the particles are ſo far ſeparated by heat as to be without each others attraction they then begin to repel each other, and will riſe from the fluid in form of a vapour, till they come to that part of the air which has the ſame gravity, they will then form clouds, &c.

Vapours thus raiſed become the original matter of *meteors:* one degree of cold condenſing them they fall in drops of *rain*; a greater degree produces a coagulation, which ſhoots like ſalts into various forms, and makes flakes of *ſnow*;‖ a third greater degree of cold produces *hail.* If cold condenſes the air the vapours cannot riſe high, but will hover near the earth's ſurface in form of a *miſt* or *fog:* if the cold be more intenſe it freezes the miſt to every twig, and to every blade of graſs. If the air be warm in the day-time, the vapour will be too fine to be viſible, yet being condenſed by the coolneſs of the evening, it will deſcend and ſettle upon the graſs in form of a *dew:* but if the evening be cold enough to freeze, then inſtead of a dew there will appear a *white froſt*.

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* Rub the bulb of a thermometer with ſpirits of wine, with a feather, and the contents will ſink as the ſpirit of wine evaporates: which ſhews that cold is produced by evaporation.

‡ A receiver filled with ſuch air as we breathe being put upon the plate of the air-pump, and the air taken away, the aqueous particles will deſcend in form of a miſt.

‖ Diſſolve ſilver in aqua fortis, then pour in a ſolution of ſalt, and the ſilver will be precipitated to the bottom in form of ſnow.

Syphon.—Ariſing from the ſame principle to ſmall heights only; for the water being raiſed by the attracting force of the ſhorter leg to the bended part, gravitation takes place in the longer leg, which carries off the water.

The *Filter* is the moſt ſimple of all the chemical inſtruments, being nothing more than a compound ſyphon, which carries off the fluid drop by drop.

Vegetation is performed after the ſame manner; the humidity of the earth being drawn or abſorbed into the plant or tree by the fibres of its roots.* It is alſo reaſonable to ſuppoſe, that the circulation of the blood and juices through the *lacteal*, *lymphatic*, and *ſanguiferous* veſſels, is owing to this attractive power and pulſive force of the heart.

Solution.—By this power fixed bodies are diſſolved by proper mediums: thus if the particles of the fluid and the ſolid have a greater attracting force than there is between the particles of the ſolids themſelves, when the ſolid is immerſed in the fluid, thoſe parts which are in immediate contact with the fluid muſt neceſſarily loſe their own coheſion, and be ſeparately attached to the particles of the fluid: and this will be the caſe till every particle of the *menſtruum* has attracted and united to itſelf ſo many particles as it can ſuſtain, then the fluid will be ſaturated therewith, and the ſolution ceaſes; but the fluid will appear as clear and tranſparent as before the ſolution began to take effect.

If to a ſolution of a ſolid and a fluid another ſolid be added, the fluid will diſſolve ſome of the latter ſolid, which is called *elective attraction*.

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* A tube hermetically ſealed, and another open, to prove that it is the preſſure of the air that ſupports the water in the tube.—In Pneumatics it will be demonſtrated, that the preſſure of the air can only ſupport the water to the height of 33 feet, but by the attraction in capillaries it may be raiſed to 100 feet or more.

Precipitation is a conſequence of the ſame cauſe. For if to a ſolution of a ſolid and fluid, another ſolution of a ſolid and fluid be added, the latter ſolid will take place of the former ſolid, which will be precipitated to the bottom. If to this precipitate another body be added, the latter body will attract the precipitate with ſome violence, and diſſolve it, then the ſolution will appear as clear as before.[‡]

Fermentation is an effect of this coheſive attraction; for an alkaline will efferveſce with an acid, or an acid with an alkaline, and changes be brought about by ſuch mixtures.

Heat, Ebullition, and Exploſion of ſundry mixtures, are owing to the violent action and great rapidity of motion among the conſtituent particles, for all heat proceeds from an attrition of the particles one among another.[†]

Having thus illuſtrated this univerſal power of attraction and repulſion, I ſhall in the next place juſt give an inſtance of the nature and uſe of another power of attraction and repulſion, which is of as ſingular a kind, as it is formed to affect two ſorts of matter, viz.

[‡] If a ſolution of ſalt of tartar be poured into a ſolution of Epſom ſalt, the precipitate becomes magneſia. ——— Oil of vitriol is uſed for diſſolutions.

Infuſion of galls, ——		
Solution of Vitriol,	black,	alkaline.
Oil of vitriol, - - -	tranſp.	acid.
Oil tartar, - - - -	black,	alkaline,

But it does not follow from this that an acid changes an alkaline, nor an alkaline an acid, by efferveſcence; but an acid will change the nature and colour of an acid, which is contrary to the general principles laid down by chemiſts.

Diſtilled verdigreas,	green,	alkaline.
Spirit of vitriol,	colourleſs,	acid.
Solution of allum,	ditto,	ditto.
Sugar of lead,	white	ditto.
Oil of tartar,	green,	alkaline.

[†] Thundering powder is made by mixing brimſtone, ſalt of tartar, and ſalt petre together; one part of the firſt, two of the ſecond, and three of the third.

the *loadſtone* and *iron.* This virtue is emitted from two parts of the ſtone or magnet, in a very fine imperceptible effluvium, and if pieces of iron be properly placed over thoſe two parts, the magnet will be as it were attracted, accumulated, and condenſed in the iron, and from thence will be emitted or communicated with much greater force and intenſity than from the ſtone itſelf.

The marks of a good magnet are *blackneſs*, *hardneſs*, and *heavineſs*. It attracts and repels iron, but touches no other ſort of matter. Its virtues may be communicated to iron by the touch, which if formed into a needle, and ſuſpended upon a point, will ſettle itſelf nearly north and ſouth; the end of the needle touched with the ſouth pole will point to the north, and *vice verſa.*

THE angle which the magnetic needle makes with the meridian is called *the variation of the needle.* About 200 years ago the variation was 16° eaſtward; after that it was found to ſtand north and ſouth, at preſent it is about 22° weſtward, ſo that in 1900 years it will have made one intire revolution, but one revolution muſt be made before it can be known with certainty. Needles ſo touched and ſuſpended will point 74° or 75° below the horizon, which is called the dipping needle; conſequently the makers of needles make the ſouth end heavier than the north end, to be a counterbalance for the attraction.

If a few ſteel filings be finely ſifted over a ſheet of paper, and the magnet placed in the middle, it will be pleaſant to obſerve how the filings are affected by the virtue iſſuing from each pole of the magnet, in curved lines and directions between the poles: from which we learn that there is a kind of circulation of this virtue from one pole to another. Dr. Halley ſuppoſes that there is a large central magnet in the bowels of the earth, which is moveable in the earth like the kernel of a nut in the ſhell, and by that means cauſes all the variety of declination of the needle, as alſo its dipping below the horizon: he alſo ſuppoſes the external ſhell of the earth to be magnetical, which not having a ſimilar motion with the *nucleus*, or internal magnet, occaſions all the variations of the needle.

The needle is attracted in vacuo as in the open air. Artificial magnets in the horſe-ſhoe form are made thus; lay two end to end, and run one pole of the magnet over them, then make them up into one magnet, by putting north and ſouth poles together.

LECTURE II.

PNEUMATICS.

VARIOUS have been the opinions of philoſophers concerning the particles of air: ſome have imagined their form to be that of a watch ſpring coiled up; others the form of a ſpunge, which contracts itſelf when any force is impreſſed upon it, and is dilated when that force is removed: but their form has hitherto remained undiſcovered, for a microſcope that magnifies ſeveral thouſand times does not ſenſibly magnify them. Though the particles are ſo exceedingly ſmall, yet they cannot make their way through metals, glaſs, or good paper, which even wine and water will do.

The air is generally conſidered as a fluid, yet differs from the general nature of fluids in three particulars; 1. it is compreſſible; 2. it cannot be congealed; 3. it is of a different denſity in every part, decreaſing from the earth's ſurface upwards.

That the air was created with the earth cannot be doubted, and ever ſince there has been a conſtant generation of air, by the mutual action of bodies upon each other, as in the fermentations of natural and artificial chemiſtry.

THAT the air is a heavy body muſt follow from the nature of the matter of which it conſiſts, and ſince thoſe particles ariſe from bodies of every kind in and upon the earth, it follows that the air muſt be of an heterogeneous nature, and various in its ſpecific gravity; for as the matter which compoſes the body of air is always variable ſo will its weight be likewiſe.

SINCE the particles of air, are ſuch as being ſeparated beyond the ſphere of corpuſcular attraction, are ſtrongly repelled from thoſe bodies, and this repellency being mutual between the particles, they do by this means conſtantly repel each other, and therefore they muſt obſerve an equal diſtance among themſelves, when therefore thoſe aërial particles are obliged by any impreſſed force to approach nearer to each other, the repulſive power will reſiſt the ſaid force with an equal momentum, and thus cauſe what we call the elaſticity or ſpring of the air.

BY reaſon of the ſpring of the air its denſity will be different at different altitudes from the earth's ſurface; for the lower parts being preſſed by the weight of the ſuperior parts, they will be made to accede nearer to each other: hence the denſity of the air is greateſt at the earth's ſurface, and decreaſes upwards in geometrical proportion to the altitudes taken in arithmetical progreſſion. Dr. Cotes demonſtrated that the air is four times more rare at the height of ſeven miles than at the earth's ſurface.

MILES,		RARITY.	MILES,		RARITY,
7	is	4	35	is	1024
14		16	42		4096
21		64	49		16384
28		256	56		65536

Hence it is eaſy to prove, that a cubic inch of ſuch air as we breathe would be ſo much rarefied at the height of 500 miles, that it would fill a ſphere equal to the orbit of Saturn in diameter.

IF the air were of an equal denſity throughout, the height of the atmoſphere might be aſcertained; for we find by experiment, that a bottle which holds a wine quart contains about 17 grains of air; but a quart of water weighs 14625 grains, then $\frac{14625}{17}=864$; which ſhews that one cubic inch of water is equal to 864 of air: alſo, a column of air the height of the atmoſphere is equal to a column of water 384 inches high, therefore 864 multiplied by 384 is equal to 331776, viz, 5 miles and 416 yards, which would be the height of the atmoſphere, were the denſity every where the ſame as at the earth's ſurface. But ſince the denſity decreaſes with the preſſure, it will be more expanded the higher we go; conſequently the altitude is indefinite, and terminates in pure ether: but though we cannot aſſign the real altitude of the air, it is certain, from obſervation, that 45 or 50 miles is the utmoſt height where the denſity is ſufficient to refract a ray of light, and that may be eſteemed the altitude of the air to the leaſt ſenſible degree of denſity.

Since the gravity of the air is ſo various that it will ſuſtain a column of mercury from 28 to 31 inches high in the barometer, take 29½ for the mean altitude, and its weight for the mean weight of a column of air of the ſame baſe. A column of mercury whoſe baſe is one ſquare inch and altitude 29½ weighs about 15℔. which is the preſſure of the air on every ſquare inch; and 12 ×12=144 the inches in a ſquare foot, and 144+15=2160℔. the preſſure on a ſquare foot; ſo that the preſſure on one ſquare foot is nearly one ton, and if we allow 14½ ſquare feet for the ſurface of a middle ſized man, he muſt ſuſtain a preſſure of 14 tons when the air is of a mean gravity. This prodigious force would cruſh man to his original duſt, if it was not counterbalanced by the ſpring of the air within him.

Air may be condenſed by art ſo as to take up only the 60th part of the ſpace it did before; and that it is a body is proved by the diving-bell,* and by a candle burning under water in a receiver, &c. Alſo, the ſpring and weight of the air is proved by a number of experiments on the air pump.[*]

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* If the bell deſcend 33 feet below the ſurface, two atmoſpheres will be upon it; if 66, three atmoſpheres, two of water and one of air: conſequently we ſee the neceſſity of having the diving machine in form of a bell.

WATER riſes in pumps, ſyphons, &c, by the preſſure of the air, to the height of 32 feet; and that the ſpring is equal to the preſſure is proved by various experiments.

THE great action of animal life, viz. breathing by the inſpiration and expiration of air, is owing to the ſpring and preſſure conjointly.

THE air lies in a fixt ſtate, and is a conſtituent part of various bodies;[†] it is alſo the pabulum of fire, and medium of ſound.[‡]

FIXED AIR.—Air in alkaline bodies may be ſet at liberty by an acid. (*ſee lect.* 1.) Fixed air is produced by mixing chalk and vitriolic acid together in a bottle, which may be placed in a baſon or reſervoir, then put the end of a crooked tube into the bottle where the chalk and acid are efferveſcing over the edge of the reſervoir, and the air ſet at liberty by the acid will riſe through the tube and diſplace the water in the jar; when the water is all diſplaced by the air the jar may be placed upon its bottom, for the fixed air cannot make its eſcape from the jar, on account of its being heavier than common air, in proportion as 157 to 100. If a lighted candle be placed in this air it is immediately extinguiſhed, and animals die in it in an inſtant, but may be recovered by ſmothering: hence we ſee the reaſon of *choak damps* in mines, which extinguiſh candles and kill the workmen. This damp is generated by an acid and an alkaline in the bowels of the earth.[§]

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[*] By weighing it in a balance;—placing the hand on an open-topt receiver;—burſting bladders, &c.

[†] Evident by taking air out of beer, water, wood, fruit, eggs, &c.

[‡] Proved by a candle burning out in an exhauſted receiver; and the ſound of a bell being ſcarcely heard in vacuo.

[§] *Properties of fixed air.*—Water impregnated with this air makes good Pyrmont water, which is an excellent medicine for the ſtone and

INFLAMMABLE, or *phlogiſticated*, air is produced by iron filings, vitriolic acid, and water, put in a bottle, as before directed. The inflammable air will riſe out of the jar and mix with common air, then if a lighted candle be put to the mouth of the jar, the air takes fire and burns to the bottom of the jar. From hence we ſee the reaſon of fire damps in mines; for this air is generated in the bowels of the earth from chalybeats, vitriolic acid, and water, ſo that when a workman puts a candle to it, it takes fire, and ſets the pit in a flame. Putreſcent bodies in church yards, *flatus alvi* of animals, air in ſtagnant water, &c. are all inflammable.*

THIS air is 11 times lighter than common air, or 8800 times lighter than water.

NITROUS air is produced by pouring ſpirits of nitre into a bottle of iron filings and following the directions for making fixed air. Nitrous air mixed with common air reduces it one-fourth or one-ſixth, and gives it a turbid, red appearance.

Two meaſures of common air decompounds one meaſure of nitrous air, but one meaſure of dephlogiſticated air decompounds two meaſures of nitrous air: in this operation the nitrous air is ſet at liberty, and may be abſorbed by water with agitation.

DEPHLOGISTICATED or pure air is produced by making red lead (free from inflammable matter) into a paſte with ſpirit of nitre, then putting it into a bottle with vitriolic acid and water, and catching it as before directed. This air is about ſix times purer than common

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and gravel, and for allaying the pain of old ulcers, on account of its diuretic and antiſceptic powers: it deſtroys animals; extinguiſhes fire; combines with lime, alkalies, and water; turns the tender vegetable blues of a red colour; and renders cauſtic alkalies and calcarious earths, mild. Fixed air conſtitutes one third part of the weight of calcarious earths. It is decompoſed by vapours of iron filings and brimſtone, or by the electric ſpark.

* Inflammable air ſuffocates animals and extinguiſhes fire; but vegetables not only thrive in it but render it reſpirable to animals; water produces the ſame effect. It throws off its earth, and is decompoſed by water.

air, and a lighted candle in it has an amazing and beautiful appearance. ‖

Common air is a mixture of dephlogiſticated air, fixed air, phlogiſton, water, &c. Prieſtley ſuppoſes that common air ſuſtains animal life by the nitrous acid it contains. It is adapted to reſpiration and the propagation of fire, which it ſupports in the atmoſphere. It is ſoluble in water and ſome other fluids, but is generally depraved by that means, and is injured by being expoſed to freſh melted nitre, &c. Reſpiration, combuſtion, agitation in water, a mixture of nitrous air, &c. ſeem in a certain degree to produce ſimilar effects upon common air. Theſe operations phlogiſticate, and contract it, ſo do the calcination of metals and the electric ſpark. If common air be highly loaded with phlogiſton, agitation in water will purify it to a certain degree; but if vegetables grow in it they abſorb the phlogiſton ſo far as to leave the air pure enough to breathe. Hence we ſee the reaſon why clumps of trees refine the vitiated air in low and marſhy grounds; alſo, why in low and cloſe rooms, where it has not a free circulation, it is generally vitiated, and conſequently very unfit for reſpiration: of which the diſeaſes incident to the ſedentary and ſtudious part of mankind are a melancholy proof: conſumptions and aſthmatic complaints being frequently the conſequence of cloſe confinement in ſuch like places.*

‖ By mixing dephlogiſticated air with air unfit to breathe, they become reſpirable.

* The pureneſs of common air may be meaſured by mixing equal parts of nitrous and common air, and according to the contraction of theſe two airs when mixed, ſo will your air be better or worſe: for inſtance, if nitrous and fixed air be mixed in equal parts they will not unite at all, but will occupy the ſame ſpace as they did before mixing; but if you mix nitrous and common air, in equal parts, this mixture will contract from about 48 to 33 or 35, and the more it contracts the better it is; but if you mix nitrous air, and dephlogiſticated or pure air, they will contract to 14, as ſhewn by the *Eudiometer*. In order to aſcertain the purity of the air at any particular place, fill a bottle with water, then carry it to the appointed place and pour out the water, you will then be ſure that you have common air of the place.

LECTURE III.

HYDROSTATICS *and* HYDRAULICS.

HYDROSTATICS is that part of natural philoſophy which treats of the nature, gravity, preſſure, and motion of fluids, and of weighing ſolids in them.

A **FLUID** is a body that yields to the leaſt partial preſſure, or force impreſſed (*ſee page 7, lect. 1*); its particles are ſo ſmall that they cannot be diſcerned by the beſt microſcopes; they are ſmooth, hard, round, and ponderous, and obſerve all the laws of motion and mutual action in common with other matter.*

FLUIDS are diſtinguiſhed into two ſorts, viz. *perfect* and *imperfect*: quickſilver is of the perfect kind, as its particles ſlide over common ſubſtances without mixing with them (*ſee page 6, lect. 1*); water is of the imperfect kind, for its particles mixing with the particles of any ſubſtance it meets with, it becomes impregnated with whatever ſtrata it runs over; hence the reaſon of mineral waters. †

ALL fluids are incompreſſible, except air; that is, they cannot be compreſſed into a leſs ſpace than they naturally poſſeſs ‡: conſequently water will not be more denſe at the bottom than at the top of the ſea.

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* That the particles of fluids are round is evident by quickſilver forced through leather; and by putting ſalt in water without encreaſing its bulk. That the particles are hard, is proved by the water rammer.

† The ſyrup of violets turns alkaline water ~~[illegible]~~ green, and acid water red ~~[illegible]~~. A ſolution of iron mine and water is turned into black by a ſolution of galls. A ſolution of allum in water is made thick by oil of tartar.

‡ Proved by the Florentine experiment of filling a globe with water, which, when preſſed with a great force, cauſed the water to iſſue through the pores of the metal.

All fluids gravitate, or weigh in proportion to their quantity of matter, not only in the air, or in vacuo, but in their own element §.

As water is not more denſe at the bottom than at the top, its preſſure upwards is equal to the preſſure downwards, at any given depth. ‖ Now as the particles of a fluid at the ſame depth preſs each other every way, and in all directions, equally, it follows, that the ſurface of a fluid muſt be perfectly ſmooth and even; for ſhould any part ſtand higher than the reſt by any force, as attraction, &c. it would ſubſide to a level with the other part by the force of its own gravity, when that force was removed: conſequently the figure of the ſurface of fluids is convex, for all the particles equally gravitating towards the centre of the earth, will take their places from it at equal diſtances on the ſurface, and ſo form part of a ſphere equal to the bulk of the earth.

Since fluids preſs equally every way, the preſſure of each particle againſt the ſide of a veſſel will be proportional to its altitude; and the preſſure of all the particles 1, 2, 3, &c. of a perpendicular column againſt the ſide will be a ſeries of numbers in arithmetical progreſſion, whoſe firſt term is 0; therefore, the remainder of all the preſſures is equal to the number of preſſures multiplied by half the greateſt preſſure; viz. the total preſſure againſt the ſides of a veſſel is as the ſquare of the altitude of the fluid; hence, if the veſſel be of a cubical form, the preſſure againſt each ſide is half that againſt the bottom, and conſequently the total preſſure upon the ſides and bottom is equal to three times the weight of the fluid on the bottom of ſuch a veſſel. The weight, preſſure, or effect of a fluid upon the bottom of any veſſel, is proportional to the altitude only, and not to the quantity of the fluid. †

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§ Proved by weighing an empty bottle in air, and in water; likewiſe weighing it in air and in water when full of water: for the water weighs as much in water as in the air, which all philoſophers till very lately have denied.

‖ Proved by tying a bladder flaccid over the end of a glaſs tube, and pouring water into it, which by its weight will bulge the bladder downwards; for while the downward preſſure is greater than the upward preſſure, the bladder bulges down; but when it is immerſed in a jar of water, and the upward and downward preſſures become equal, the bladder will be even with the end of the glaſs; but when the upward preſſure is greater than the downward, the bladder is drove into the tube, by the ſuperior force of the upward preſſure of the water in the jar above that in the tube.

When any body is immerſed in a fluid, it loſes juſt ſo much of its weight as is equal to the weight of an equal bulk of the fluid; but the weight loſt by the body is gained by the fluid, which will be ſo much heavier than before. ‡

If a body could be found without weight, it would, if placed on the ſurface of a fluid, float thereon without any part being immerſed therein; for being devoid of gravity, it could have no force to diſplace any particles of the fluid, and ſink therein.

If any heavy body lighter than an equal bulk of the fluid be placed on its ſurface, it will ſink or deſcend therein till it has removed or diſplaced ſo much of the fluid whoſe weight is equal to that of the body; for the preſſure upwards and downwards on the under ſurface of the body is equal: hence the whole ſolid is to the immerſed part as the ſpecific gravity of the fluid to that of the ſolid. If a ſolid equal in weight to an equal bulk of the fluid be immerſed therein, it will take any ſituation in the fluid, without any tendency to aſcend or deſcend therein. If a body heavier than an equal bulk of the fluid be immerſed therein, it will deſcend by the exceſs of its gravity above that of the fluid; for it will be reſiſted by the force of an equal bulk of the fluid, which will deſtroy juſt ſo much of the gravity of the ſolid, and the exceſs of gravity will make it deſcend.

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† Hence a very ſmall quantity of a fluid may be made to counterballance any quantity of a fluid, how great ſoever; which is called the *hydroſtatic paradox.* For if a cylinder of three inches diameter and five inches high, with a looſe bottom, and its top made faſt, with a glaſs tube put through the top, be filled with water and hooked to a ſcale beam, it will weigh about 1 ℔. if 2 ℔. be put in the other ſcale, the water will riſe in the tube, by the preſſure of the bottom, to ſuch a height that it will counterbalance the weight at the other end. If 3 ℔. it balances 3 ℔. &c.

‡ This is the fundamental principle of every hydroſtatic proceſs; particularly of the whole doctrine of ſpecific gravity.—— Proved by a ſolid cylinder and bucket. The ſolid immerſed in water loſes as much weight when in water as an equal quantity of water weighs; or as much weight as a bucket full of water weighs:

FROM what has been premiſed it will be eaſy to underſtand, that the lighteſt body may be made to ſink in the heavieſt fluid: on the other hand, the heavieſt bodies may be made to ſwim in the lighteſt fluids.* Hence the reaſon of trying the different gravity, denſity, or ſtrength of ſpirituous liquors, by the hydrometer, or water-poiſe; for the ſtronger any fluid is, the greater will be its reſiſtance to any ſolid immerſed, conſequently the hydrometer cannot ſink ſo far in a heavy as in a lighter fluid, and as ſpirits are lighter than water, the hydrometer will ſink deeper in ſpirituous liquors than in water, as is eaſily ſhewn by the graduated neck of the inſtrument.

THE *hydroſtatic balance* is an inſtrument invented on the ſame principles; by it we have a moſt uſeful and ready method of finding the various comparative or ſpecific gravity of fluids and ſolid bodies to the greateſt accuracy. †

THE

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* Cork may be ſunk in quickſilver, or water, by keeping the upward preſſure off; and gold may be made to ſwim in water by putting it in the end of a tube, to keep the downward preſſure off; and when immerſed 19 times its thickneſs under water, the upward preſſure will ſuſpend the guinea at the end of the tube. For gold is 19 times heavier than water. *See the table of ſpecific gravity.*

† The application of Hydroſtatics to the ſeveral uſes of life, will be evident from the following examples:

A guinea weighs in air 129 grains, forceps 22
Ditto loſes in water, 9 grains.

Rule. Divide the weight in air by what the guinea loſes in water, and the quotient is the ſpecific gravity. $\frac{129+22}{9}=17$ nearly.

A ſhilling weighs in air 82 grains, forceps 22.
Loſes in water, — 10 grains———

Then $\frac{82+22}{10}=10{,}4$ nearly, &c.

Having

The ſpecific gravity of fluids is eaſily determined by weighing one and the ſame ſolid body in them ſeverally; for if we ſuppoſe the balance in equilibrium with the body ſuſpended in the air, the equilibrium will be deſtroyed when the ſolid is immerſed in the fluid, and muſt then be reſtored by weights put into that ſcale to which the body is appended. Theſe weights will ſeverally expreſs the gravity of an equal bulk of the reſpective fluids; conſequently they may be compared with each other, and with the gravity of common water, which is uſually called 1,000 in the tables, &c.

In the ſame manner, if divers ſolids are firſt weighed in air, and afterwards immerſed in the ſame fluid, the equilibrium will be reſtored by putting in as much weight as is equal to the weight of the ſame bulk of water. The gravity of every ſolid is thus compared with water, and with each other, as in the following table.

A ſolid body lighter than water muſt be connected with ſomething heavier than water.*

The ſpecific gravity of fluids may be thus aſcertained: take a tube with quickſilver in it, and put another tube into it, then pour water upon the quickſilver in the tube, and the preſſure of the water upon the quickſilver will force it up in the tube, in proportion to the denſity.

TABLE

Having the ſpecific gravity of gold to ſilver, as 17 to 10, and of a compound, as a guinea and a ſhilling, &c. to find the gold and ſilver employed in the compoſition, obſerve the following *Rule:* As the difference of the ſpecific gravities of the compound and the lighter body is to the difference of the ſpecific gravities of the heavier body and compound, ſo is the gold to the ſilver.

* *Rule.* Subtract the weight in water of the compound by what it weighs in air, and what the heavy body loſes the remainder is the ſpecific gravity.

A cubic foot of common water weighs exactly 1000 ounces avoirdupois, or 62 pounds and a half: the troy pound is to the avoirdupois as 14 to 17; and the avoirdupoiſe ounce to the troy ounce as 51 to 56.

To find the preſſure againſt any ſluice or bank that pens the

water

TABLE OF SPECIFIC GRAVITIES, &c.

Fine gold, - -	19,64	*Common water,* -	1,00
Guinea ditto, - -	17,15	*Oil of vitriol,* - -	1,70
Mercury, - -	14,00	*Milk,* - - -	1,03
Lead, - - -	11,32	*Fir,* - - - - -	,55
Fine ſilver, -	11,09	*Cork,* - - - - -	,24
Shilling ditto, -	10,00	*Linſeed oil,* - -	,93
Copper, - - -	9,00	*Oil of turpentine,*	,79
Braſs, - - -	8,00	*Spirits of wine,*	,73
Iron, - - - - -	7,64	*Spirits of vitriol,*	1,20
Tin, - - - -	7,32	*Spirits of nitre,*	1,31
Diamond, - -	3,42	*Canary wine,* - -	1,03
Glaſs, - - -	3,15	*Urine,* - - -	1,03
Marble, - -	2,70	*Aqua fortis,* - -	1,30
Slate, - - -	2,50	*Alum,* - - -	1,71
Bone, - - -	2,00	*Honey,* - - -	1,45
Ivory, - - -	1,82	*Roſin,* - - -	1,19

water of a reſervoir. *Rule.* Multiply the area of the ſluice under water by the depth of the centre of gravity in feet, and that product again by $62\frac{1}{2}$; the product will be the number of pounds required. *Example.* If the length of a ſluice be 20 feet and the depth 5 feet, then $20 \times 5 = 100$, area; and $100 \times 2\frac{1}{2} = 250 \times 62\frac{1}{2} = 15625$ ℔, equal to 7 tons nearly; ſince the weight of bodies is always as the ſpecific gravity in equal bulks: therefore, if the magnitude of any body be multiplied by the ſpecific gravity, the product will be its abſolute weight. Suppoſe I want to know what weight of lead will cover a building whoſe area is 4050, and thickneſs of lead $\frac{1}{100}$ of a foot; then $4050 \times \frac{1}{100} = 40{,}5 \times 11{,}325 = 458460$ ℔.

To find the magnitude of any thing, when the weight is known. *Rule.* Divide the weight by the ſpecific gravity in the table; the quotient is the magnitude ſought. *Example.* What is the magnitude of a piece of braſs whoſe weight is 10 ounces. Then $\frac{10}{8000} = {,}00125$ of a cubic foot, and $,00125 \times 1728 = 2\frac{16}{100}$ cubic inches. Alſo, by knowing the magnitude and weight we can find the ſpecific gravity. *Rule.* Divide the weight by the magnitude in cubic feet. Thus ſuppoſe a piece of marble 4 cubic feet, which weighs 603 ℔, or 10800 ounces; then $\frac{10800}{4} = 2700$, the ſpecific gravity required,—as per table.

By *Hydraulics* we are to underſtand the ſcience of the motion of fluids, and the conſtruction of all kinds of machines relating thereto; alſo the nature of ſprings, &c.

The moſt natural motion of fluids is that ariſing from the force of their own gravity; by which thoſe parts which ſtand higheſt preſs upon others below them, till by that means they riſe to the ſame horizontal level. Hence we have conduits often ſupplied with water from ſprings which lie above them; and cocks to ſupply the inhabitants of a town with water, by pipes proceeding from a reſervoir above the higheſt part of the town. Hence alſo the deſcent of water in rivers, &c. from ſprings and ſources above the common ſurface of the earth; and the breaking out of ſprings at the bottoms and on the ſides of hills, from ciſterns and reſervoirs in the internal part above them, which receive their waters from rain, dew, &c. diſtilling through the pores or crevices, and chaſms of the upper part of the earth.

By the preſſure of the fluid it may eaſily be conveyed over vallies and hills, by bended pipes or ſyphons, from ponds or reſervoirs in a higher ſituation; which the ancients being ignorant of, were at vaſt pains and expence very often to effect. Hence the running of water through the bended ſyphon accounts for the odd phænomenon of intermitting and reciprocating ſprings; and alſo in that inſtrument called Tantalus's cup: the riſe of water in wells is alſo owing to the weight of that in the ſubterranean ciſterns, from whence they are ſupplied by proper canals or ſprings.*

From the preſſure of the ſuperior fluid we have the invention of a natural fountain, which playing from the ſmall orifice of an adjutage at the bottom, will ſpout very beautifully nearly to the height of the water from the fountain, but cannot reach that altitude, by reaſon of the air's reſiſtance.

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* A ſyphon will raiſe water to the height of 29 feet only, by the preſſure of the air; but if an air pump be placed upon the bended part, it will raiſe water to the ſame height as in the common water pump. Tantalus's cup has a concealed ſyphon in the body of the figure.

FROM this preſſure of fluids we can eſtimate the various momenta or forces of ſeveral jets ſpouting through the ſides or bottoms of veſſels, at different depths below the ſurface; for the momenta of fluids, as well as ſolid bodies, is compounded of the quantity of matter and the velocity; but in ſpouting fluids the quantity of the fluid iſſuing through the ſame hole in the ſame time, is always as the celerity of its motion: whence the momenta of ſpouting fluids are always proportional to the ſquares of the velocities, or quantities of matter iſſuing out in a given time.*

THE effect of the common pump is from the ſame principle as the ſyphon; for the bucket, or ſucker, raiſes a column of water above it in the barrel, and makes a vacant ſpace, or greatly rarefies the air in the barrel and pipe below it; whence the water will riſe in the pipe and barrel by the preſſure of the atmoſphere on the water in the well.†

THE moſt conſiderable of all water engines is that called the *fire engine*. The motion of the water in this engine is effected by the preſſure of the air, by the force of piſtons, and by the ſpring of condenſed air.

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* A pipe fixed four times as deep as another of the ſame diameter, will diſcharge twice as much in the ſame time; if nine times as deep it will diſcharge three times as much; if ſixteen times as deep, four times as much, &c. Pipes alſo diſcharge agreeably to the ſquares of their diameter; *viz.* a pipe twice the diameter of another will diſcharge four times as much; three times the diameter, nine times as much, &c.

† Suppoſe the diameter of a pipe to be two inches, barrel three inches,—circles are in proportion to one another as the ſquares of their diameter, 2×2=4, and 3×3=9; *viz.* the pipe and the barrel are as 4 to 9: now as it it is admitted that the preſſure of the air raiſes the water, the water cannot riſe in the pipe, as there is above double the weight of air on the barrel that there is on the pipe; ſo a valve is placed in the barrel or pipe, to ſtop the water from falling down: now as there are 5 ſquare inches more in the barrel than the pipe, there will be a preſſure of 75 ℔. more on the barrel than the pipe, and that great weight muſt be overcome, beſides the friction of the piſton, before water will riſe.

The laſt cauſe or motion of fluids is that of attraction, which is mentioned in lecture firſt.

Smoke does not riſe by its poſitive levity, but by its being lighter than air.

LECTURES IV and V.

OPTICS.

THE nature of viſion, and the various phænomena of viſible objects by rays of light, reflected from mirrors and tranſmitted through lenſes, conſtitutes the delightful ſcience called *Optics*.

Light conſiſts of inconceivably ſmall particles of matter of different magnitudes, flowing from a luminous body in right lines, in all directions, with great velocity, and decreaſes in power as the ſquare of the diſtances increaſe.*

That the particles of light are inconceivably ſmall is evident from the greateſt quantity of light, in its greateſt denſity or flame, having no ſenſible weight; which is always proportional to the quantity of matter in all bodies: and as thoſe particles pervade the pores of glaſs, &c. and likewiſe, as the ſtroke we receive by a particle of light has no ſenſible force, which, on account of its prodigious velocity would be very great, if it were of any conſiderable magnitude.

The velocity of the rays of light ſurpaſes that of all other bodies we know of. By obſervations of the eclipſes of Jupiter's ſatellites, it is found that light is about 8 minutes in coming from the ſun to the earth, viz. at the rate of 200000 miles in one ſecond of time, which is 800000 times greater than the velocity of ſound.

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* A candle will fill a ſphere of four miles in diameter inſtantaneouſly; and as it is evident (by placing a row of candles before a paſtboard with a hole in it) that light goes in all directions, a great number muſt enter the pupil of the eye, and ſo paint the image of the candle on the retina. A candle may be lighted and extinguiſhed without loſing any ſenſible weight, and at the ſame time fill a ſphere of four miles in diameter with the particles of light.

Whilst the rays of light continue in any medium of uniform denſity they move in right lines; but meeting with a denſer medium, as air, (and moving with ſuch a great velocity are refracted towards the perpendicular) they are bent out of their right courſe. Water being denſer than air refracts the rays more. Glaſs in a ſtill greater degree.†

The rays of light are diſtinguiſhed into three ſorts, viz. *parallel*, *converging*, and *diverging*. Parallel rays are ſuch as always keep the ſame diſtance with reſpect to ſenſe; ſuch as the ſun's rays in their natural ſtate. Converging rays are ſuch as in their courſe approach nearer and nearer; as the rays of the ſun collected by a convex lens, &c. Diverging rays are thoſe which proceed from a point, and in their progreſs recede from each other. ‡

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† To prove the refraction of the rays of light by experiment. 1. Place a ſhilling in a baſon, and ſtand ſo far off that you cannot ſee the ſhilling; then pour in water and the ſhilling will appear. 2. Take a board with three braſs nails in it, not in one right line but in an angle, put in water and the nails will appear in a right line, or in proportion as 3 to 4 when out of air into water; if the refraction be out of air into glaſs, then as 17 to 11, or 3 to 2.— 3. If a tumbler be half filled with water, a ſhilling put into it, and inverted upon a plate, there will appear a piece as large as a half crown at the bottom, and another piece as large as a ſhilling floating upon the ſurface; owing to the rays being refracted and magnified.

‡ The form and properties of theſe rays, of the different ſorts of glaſſes, and other parts of this lecture, are further illuſtrated and explained at the time of delivery by tranſparent paintings and diagrams. As theſe paintings or drawings are the only means by which moſt parts of optics can be demonſtrated, it is thought neceſſary to give this information to the reader, to avoid the too frequent repetition of the ſame note, and as a general apology for the omiſſion.

The point where the rays are collected is called the *focus*, or burning point; becauſe the ſun's rays being there united in a ſmall compaſs, are greatly condenſed, by which means their action or heat is proportionably increaſed: therefore, objects placed in that poſition will be greatly heated, burnt, or melted.

Glasses are of two kinds, viz. *mirrors* and *lenſes*. A mirror, or ſpeculum, is that which from one poliſhed ſurface reflects the rays of light; and theſe are convex, concave, and plane. A lens is any tranſparent body, as glaſs, &c. through which the rays of light will freely paſs, and is of a proper form to collect or diſperſe them; of theſe there are a *plane lens*, *plano-convex*, *double-convex*, *plano-concave*, *double concave*, *meniſcus*, *multiplying glaſs*, and *priſm*.

The different properties and effects of theſe glaſſes, in reflecting and refracting the rays of light, entirely depends on that fundamental law, *That the angle of incidence is equal to the angle of reflection*.*

Convex Mirror.—Diverging rays form the focus behind the glaſs, but nearer the glaſs than the center. Parallel rays—the focus is behind the glaſs, but nearer the center than before. Converging rays—the focus is before the glaſs. §

If an object be placed before a convex mirror the image is erect, diminiſhed, and appears crooked.

Concave Mirror.—Diverging rays—the focus is before the glaſs at two-thirds from the ſurface towards the center. Parallel rays—the focus is before the glaſs, at half the diſtance of the center. Converging rays the focus is before the glaſs, but nearer than before.‖

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* The angle of incidence being equal to the angle of reflection, it is proved, that if an incident ray fall upon a reflecting body, the reflected angle will be equal to the incident one; or make the ſame angle with the perpendicular.

§ *Rule to find the focus.*—Multiply the diſtance and radius together, divide that product by the ſum of the radius added to twice the diſtance, and the quotient will be the diſtance of the focus required.

If an object be placed before the mirror, but nearer than the center, the image is behind the glaſs, erect, magnified, and appears crooked. If an object be placed before the mirror, at a conſiderable diſtance from the center, the image will appear before the glaſs, inverted, diminiſhed, and crooked. But if the object be placed in the center of the ſphere of which the mirror is a portion, the object and image meet.

Plain Mirror.—Diverging rays—the focus is behind the glaſs, at the ſame diſtance the radiant is before it. Parallel rays go on parallel, and are reflected parallel. Converging rays—the focus is before the glaſs.

When an object is placed before a plain mirror, the image appears as far behind the glaſs as the object is before it, and erect; hence appears the reaſon why a perſon may ſee his whole image with a glaſs but half as long and broad as himſelf.

‖ *Rule to find the focus.*—Multiply the diſtance and radius together, divide that product by the difference between the diſtance doubled and the radius; the quotient is the diſtance of the focus required.

Now by a due conſideration of the properties of converging and diverging rays, it is plain they are converſive; for the incident rays, radiant and focus in one, being but the reflected rays, focus, and radiant in the other; and as the ſun's rays are parallel among themſelves, they will all be reflected to that point, and there burn in proportion to the quantity of rays collected by the mirror.—Hence appears the reaſon why concaves make ſuch excellent burning glaſſes *Eaxmple.* Suppoſe the diameter of a mirror is 7 inches, ſolar ſpot ,2 of an inch; then $7 \times 7 = 49 \div ,04 = 1225$ the rays are condenſed more than the ſun's; and as the heat of a culinary fire is computed to be 35 times greater than the heat of the ſun, then $\frac{1225}{35} = 35$ times greater than the heat of a common fire; no wonder then of its burning intenſely.

The rule for finding the focus is the ſame as for the convex mirror, with this difference only, that there the focus was behind the mirror, and here it is before it.

A remarkable optical deception takes place with a concave mirror, and two bottles half filled with water, one of them coloured. The coloured water appears in its proper place, while the common water appears inverted: if the common water be let ſlowly out, the bottle will appear as if filling with water; and when the laſt drop is running out the bottle appears full, and then the deluſion ceaſes. I preſume the deception is owing to our not ſeeing water ſuſpended in a bottle.

A PRISM was formerly called a lens, but at preſent is not ranked amongſt them; it is ground in a triangular form, each angle being 60° it refracts the rays of light into different degrees: the leſs refracted rays which fall neareſt the perpendicular are red, the next orange, then yellow, green, blue, indigo, and violet, which are the ſeven primary colours of light. †

GLOBE.—A glaſs globe filled with water becomes a lens, a burning glaſs, &c. ‡ Diverging rays—the focus goes beyond the center. Parallel rays—the focus is at the center Converging rays—the focus is nearer than the centre. A hemiſphere forms its images at double the diſtance of a globe. A

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† If a hole be made in a window ſhutter to admit a ray of light, and the priſm held in the ray, the colours will be beautifully painted on the wall, and correſpond to the ſeven notes of muſic; *viz.* they occupy according to the undermentioned proportion; red 45°, orange 27°, yellow 48°, green 60°, blue 60°, indigo 40°, violet 80°, = 360.

‡ If the globe be held in the ſun's rays it will burn very intenſely. Likewiſe, if held in the ſun's beams in a dark room it will paint the image of the external and internal rainbows, by the ray being differently refracted and reflected; for the outer bow is produced by two refractions and two reflections: its breadth is from 50° 57′ to 54° 7′; *viz.* its breadth is 3° 10′.

The inner bow is cauſed by one refraction and one reflection, its diſtance from the outer bow being 8° 55′; its breadth is from 48° 17′ to 42° 2′; *viz.* its breadth is 1° 45′: conſequently the rainbow is formed by drops of rain refracting and reflecting the rays of light, which come to the eye of the ſpectator, who has his back turned towards the ſun, and views the colours painted upon a black cloud behind him.

‘It is a bow of no hoſtile intention; a bow painted with variegated colours on the diſburdened cloud. How vaſt its extent! how delicate the texture of that ſhadowy arch! Elegant its form, and rich its tincture; but more delightful its ſacred ſignificancy: while the violet and the roſe bluſh in its beautiful aſpect, the olive-branch ſmiles in its gracious import. It writes, in radiant dies, what the angels ſung in harmonious ſtrains,

‘*peace*

A DOUBLE CONVEX LENS is formed from two ſegments of a globe; conſequently its focus will be formed according to its convexity. Diverging rays—the focus is affirmative, at nearly double the diſtance from the center of the ſphere of which it is a portion. Parallel rays—the focus is at the center of the ſphere. § Converging rays—the focus is between the center and ſurface.

IF an object be placed at the center of a convex lens, the image, after refraction, is inverted and magnified; which is the foundation of the *magic lantern* and *ſolar microſcope:* for the rays go on diverging, and will form an image at any diſtance.

IF an object be placed at the double radius or circumference of the ſphere of which it is a portion, the image will appear at the ſame diſtance inverted. Hence we ſee the reaſon of convex lenſes being of ſuch uſe to painters, to draw a copy as large as life, or in any aſſigned proportion.

ANOTHER wonderful property of a lens is its negative focus, which I met with accidentally in making experiments with lenſes, and which I find has not been taken notice of by any writer on optics, or at leaſt not demonſtrated by them. || To account for negative fo-

' *peace on earth, and good will towards men.* It is the ſtamp of inſurance for the continual welfare of this preſent world, and a comfortable token of a better ſtate and happier kingdom; a kingdom where a rainbow is repreſented as ſurrounding the throne, to intimate, that ſtorms ſhall beat no more, but an eternal ſpring of joy and felicity bloom for ever.

§ Hence a convex lens becomes a burning glaſs; for the denſity of the ſolar rays are as the area of the glaſs directly, and ſquare of the focal diſtance inverſely. Thus ſuppoſe two lenſes 3 inches diameter each, the focus of one 12 inches, and the other 24; then $\frac{9}{144} : \frac{9}{576} :: 1 : 4$; ſo that the ſhorter focus'd glaſs condenſes the ſolar ſpot four times more than the longer.

|| Having got a parcel of lenſes framed, I found the joiner had miſplaced them; ſo to find the proper focus I held them againſt the wall, the window being radiant. I took up the plano-convex in-

cuſes we muſt ſuppoſe the lens to be half pore and half particle; now the rays of light falling upon ſuch a glaſs,

ſtead of the plano-concave, and by applying the ſheet of paper to receive the negative focus, I obſerved a focus on the paper, but conſiderably different from what I thought it ſhould have been. This excited my curioſity; I tried the experiment again, and found a focus upon the wall at a proper diſtance; and a negative, or ſecondary focus at $\frac{1}{8}$ the diſtance of the other, upon the ſheet. Here I was at a ſtand, for I found myſelf unable to account for ſuch an odd phænomenon; I therefore applied to all the authors on Optics by me, ſuch as Newton, Martin, Smith, Emerſon, Prieſtley, and ſeveral others, but found nothing ſatisfactory. I then applied to my lenſes again for further information, and the undermentioned is the reſult of my experiments:

Double convex, proper focus	12	inches, ſecondary	3	inches.
———	24	———	6	———
———	36	———	9	———
———	56	———	14	———
———	72	———	18	———
Plano-convex, proper focus,	24	in. convex ſide,	12	in. —
———	24	———	3	———

When the convex was towards the radiant of the plano-convex lens, its negative was 12 inches; but when the plain ſide was towards the radiant, only three inches.

I communicated theſe experiments to ſome of my acquaintances, one of whom referred me to *Martin's New Elements of Optics*, who ſays (page 80) ‘ that a ſecondary focus is formed by ſeveral internal reflections and refractions: ’ and in the notes he ſays that he has magnified objects much more this way than in the common way, with a glaſs of 12 or 18 inch focus, whoſe ſecondary focus was 2 or 2½ inches, and ſo ſays no more: what he means by this ſecondary focus is the ſame, I ſuppoſe, as obſerved by me, but not the ſame focal diſtance.

I then examined what reflection and refraction would produce, by ſilvering lenſes of ſeveral focal diſtances; and found that when a double convex lens was ſilvered on one ſide, the rays reflected from the firſt ſurface were made to diverge, and thoſe tranſmitted through the firſt ſurface were reflected by the ſecond ſurface, and made to converge to a focus at the diſtance of one-fourth of the radius of which it is a portion. I ſilvered the plano-convex on the plain ſide, whoſe focus was 24 inches, and found that its negative focus was at 12 inches: now as it has been demonſtrated that if rays fall upon a convex ſurface, are made to go converging to the plain ſilvered ſurface, they are reflected back to a focus at the centre of the ſphere of which it is a portion. I ſilvered the ſaid lens on the convex ſide, and found that its negative focus was a glaſs, will be but half of them tranſmitted into the glaſs, by the firſt ſurface; and we muſt alſo ſuppoſe the further ſide of the glaſs to be half pore and half particle; then half the rays which enter the firſt ſurface will be reflected back by the ſecond ſurface, and made to converge to a focus before the glaſs, called a *ſecondary* or *negative* focus: ſo we ſee the reaſon why ſeveral images are formed by the internal reflection and refraction.

A PLANO-CONVEX LENS forms its images at double the diſtance of a convex lens; ſo the ſame rules will hold good with doubling.

DOUBLE CONCAVE LENS.—Diverging rays—the focus is negative, at two-thirds from the center. Parallel rays—the focus is at the center of the ſphere of which it is a portion. Converging rays—the focus is negative, at the circumference.

A CONCAVE diminiſhes the object, but the image is erect.

A PLANO-CONCAVE forms its images at double diſtance, &c.

A MENISCUS has ſometimes the property of a convex lens, and ſometimes of a concave, but is now very ſeldom uſed.

A MULTIPLYING GLASS forms as many objects as it has ground ſides.

HAVING now explained the nature and properties of lenſes, I ſhall ſhew how they may be made ſubſervient to the various purpoſes of man.

THE eye is the noble organ of ſight; it conſiſts of various coats and humours, of which three are remarkable; *viz.* the *aqueous*, *vitreous*, and *chryſtaline.*

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at three inches diſtance, the ſame as a double convex; which demonſtrates that the firſt ſurface neither refracts nor reflects the rays to a focus. From hence it appears that burning glaſſes may be made at one-fourth of the uſual expence, and to burn four times as ſtrong.

At the bottom of the eye is the *retina*, or optic nerve, upon which the images of objects are painted.*

The chryſtalline humour is of ſuch convexity, that in a ſound eye its form is that of a convex lens; and its focus falls preciſely on the retina, and makes diſtinct viſion. Any rays more than ſix inches diſtant, when they enter the eye become nearly parallel; and therefore, to a ſound eye diſtinct viſion cannot be affected at leſs than ſix inches.

Since then there is a certain and determined degree of convexity in the chryſtaline humour for forming the images of objects on the retina, if it happens that the convexity be more or leſs than juſt, the focus of rays will fall ſhort of, or go beyond, the retina; and in either caſe will cauſe indiſtinct viſion: the firſt is the caſe of ſhort ſighted perſons, the latter of the aged. A ſhort ſighted perſon having the convexity of the eye too great, the rays are united, and form the image before they reach the retina. The other defect ariſes from quite a contrary cauſe; *viz.* the chryſtaline humour being too flat, as is generally the caſe with old people.

The single microscope is nothing but a convex lens of a ſhort focal diſtance.

The compound microscope is conſtructed of three glaſſes; *viz.* an object glaſs, and two eye glaſſes.

The solar microscope is conſtructed of a large lens, to throw light upon the object, and only one convex lens, of a ſhort focal diſtance, to magnify the object. A plain mirror reflects the light of the ſun upon the object, which is placed in a dark room, and magnifies it in proportion to the focal diſtance of the object glaſs to the breadth of the room.

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* *Oh,* SIGHT ! *the mother of deſires,*
What charming objects doſt thou yield:
'Tis ſweet when tedious night expires,
To ſee the roſy morning gild
The mountain tops, and print the fields;
'Tis ſweet the bluſhing morn to view,
And plains adorn'd with pearly dew.
BLACKMORE.

The opera glass is conſtructed with two lenſes; a plano-convex object glaſs, and a concave eye glaſs. The focus of the concave falls within the focus of the convex; conſequently the image is viewed erect. To find the magnifying power—divide the focal diſtance of the object glaſs by the focal diſtance of the eye glaſs, and the quotient is the magnifying power.

The Galilean telescope is of the ſame conſtruction as the opera glaſs.

The refracting telescope has three eye glaſſes, and one object glaſs: the three eye glaſſes ſtand at double their focal diſtance from one another, and the magnifying power is computed as in the opera glaſs.

Doland's patent telescope is formed with a large object glaſs, which is compoſed of two joining glaſſes of different denſities, the one correcting the errors of the other, and by taking off the coloured rays the image becomes bright and quite diſtinct; conſequently the field of view is larger, and the image, formed by refraction, is viewed only by one eye glaſs.

The reflecting telescope exceeds all others in its magnifying powers and portable ſize. At the end of the great tube, adjoining to the ſmall tube, is a large convex mirror, with a hole through its middle, which receives the rays from objects, and reflects them to a focus: a ſmall mirror is placed facing the hole in the great mirror, which reflects the image parallel to the eye glaſſes.

The diagonal mirror is a pleaſing inſtrument for viewing prints: it is conſtructed of a double convex lens and a plain mirror, placed in an angle of 45° degrees to a print placed in an inverted horizontal poſition, which, when viewed with the lens appears very much magnified.

The camera obscura is formed on the ſame principle as the diagonal mirror; it is ſet at the ſame angle againſt the landſcape, and reflects it upwards on paper or glaſs, where the landſcape may be drawn.

The scioptic ball is nothing more than a convex lens of a long focus; for being placed in a window-ſhutter, the rays from an object croſſing one another give a large picture of the object in its proper colours.*

The polyhedron is conſtructed of four plain mirrors, ſet perpendicular, two and two, which reflect the image of an object ſeveral times.

The cistula is conſtructed of two mirrors, ſet parallel and perpendicular to each other.

The cylinderical mirror is a pleaſing inſtrument, which rectifies deformed pictures.

The magic lantern is formed on the ſame principles as the ſolar microſcope, with only this difference, that here the place of the ſun is ſupplied by a candle.

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LECTURE VI.

ELECTRICITY.

ARTS and ſciences, like kingdoms and nations, have ſome happy period of ſplendor and glory, in which they more than ever attract the human attention, and become the favourite purſuit of the age; but theſe periods are ſoon over, and a few years of luſtre are often overbalanced by centuries of oblivion. Of this kind is Electricity; one of the moſt pleaſing and ſurprizing among all the branches of natural philoſophy that ever were cultivated by man. After it began to ſhew the extent of its power, and was found to be one of the greateſt agents of nature, it was profitably cultivated, and brought to a ſtate in which it ſeems further to engage the general attention, and promiſe to its followers more munificent rewards.

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* *By means of which woods, hills, and dales appear,*
Flocks graze the plains, birds wing the ſilent air:
In darken'd rooms, where light can only paſs
Thro' the ſmall circle of a convex glaſs,
On the white ſheet the moving figures riſe;
The foreſt waves, clouds float along the ſkies.

ELECTRICITY, by ſtriking the ſenſes in a particular manner, affords pleaſure; and is of uſe to the ignorant as well as the philoſopher, the poor as well as the rich: we are pleaſed with beholding its penetrating light; we admire its attraction and repulſion; ſurprized by the ſhock, and terrified by the exploſion. But when we conſider it as the cauſe of *thunder*, *lightening*, the *aurora borealis*, and other phænomena of nature, whoſe direful effects we can in part imitate, explain, and even avert, we are then involved in a maze that leaves nothing to contemplate but the inexpreſſible and permanent idea of admiration and wonder.

THE term Electricity is derived from *electron*, the Greek name for amber, which Theophraſtus, about 300 years before the birth of Chriſt, found to attract light bodies, ſuch as chaff and pieces of ſtraw, &c. but now it is extended to ſignify the ſaid power in all other bodies wherein that power reſides.

ALL bodies that we know of have more or leſs of this electric matter, or fluid, in them; which lies dormant till put into motion by rubbing, and then in a dark room it appears like fire.

SOME bodies do freely admit this fluid to paſs through their pores, and others do not; the former of theſe are called *non-electrics*, or *conductors*:* the latter, which do not admit the electric fluid to paſs through their pores, are called *electrics*, or *non-conductors*; ‡ but if any electric be wetted with water, the water that adheres to it becomes a conductor.

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* *Conductors.*—Gold, ſilver, copper, braſs, iron, tin, lead, ores, charcoal, fluids, ice, ſnow, ſaline ſubſtances, ſmoke, vapours, &c.

‡ *Non-conductors,*—Glaſs, precious ſtones, reſins, amber, ſulphur

The quantity of electric fire which every body has lying dormant in it, is called its *natural quantity*; and this would always remain motionleſs and inviſible if nothing diſturbed it; but when any more is forced into it, the whole is inſtantly put in motion thereby, and begins to run out of the body if it can find a paſſage.

The earth is the grand ſource of electric fire, and no additional quantity can be forced into any body but from the earth. If the body be a free conductor, and have a free communication with the earth, by means of a conducting body, the electric fire will run as faſt to the earth as it is driven into the conductor; but if the conducting body be cut off by means of any non-conductor, ſome of the electric fire will be forced into the conductor, by which means it will have more than its natural quantity, and the earth from whence it was taken will have ſo much leſs; which proves that the electric fluid may be condenſed, or compreſſed into a leſs ſpace than it naturally poſſeſſes.

If the conducting body be round, and properly inſulated, the electric fluid will come from it in a very condenſed ſtate, but from a point it comes off inſenſibly; which proves that ſharp pointed wires are as free conductors as open tubes are for water.

When a body has more than its natural quantity of this fluid it is ſaid to be electrified *poſitively* or *plus*; and when leſs than its natural quantity it is ſaid to be electrified *negatively* or *minus*:—the machine may be ſo contrived as to electrify either of theſe ways. †

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phur, baked wood, wax, ſilk, cotton, feathers, wool, hair, paper, white ſugar, air, oils, aſhes, dry vegetable ſubſtances, &c.

When a body is to be uſed as a non-conductor it ſhould be well wiped with a warm linen cloth, to clear it from damps and the humidity of the air.

† When two bodies are electrified *poſitively*, or *minus*, they repel each other: but when one is electrified *plus*, and the other *minus*, they attract each other; as ſhewn by experiments with the Leyden phial and electrometer.

The electrical fluid accelerates the motion of fluids, as is evidently proved by various experiments.

If a glaſs plate be coated with ſome conducting ſubſtance on both ſides, ſo that the coating do not come ſo near the edge as to render it unfit to be charged, and if one ſide touch ſome conducting, electrified, inſulated body, and the other ſide communicate with the earth; in this caſe the body will become charged on one ſide poſitively, and on the other negatively: for no body can have an overcharge on one ſide, without the other ſide be ſo ſituated as to part with its natural quantity of this fluid, which it cannot do if it do not communicate with the earth; for an inſulated jar cannot be charged, as ſhewn by experiment: ſo that to reſtore the equilibrium a conducting body muſt touch both ſides, and if the equilibrium be reſtored through the human body it gives a ſudden motion, by contracting the muſcles through which it paſſes, and cauſes a diſagreeable ſenſation called the *electrical ſhock*.

Water and ſalt will collect the electric fire, the one being an electric and the other a non-electric: hence the ſea will become a large electrical machine; when violently agitated by winds, collecting on its troubled ſurface the fire from beneath, and looking in the night as if it was all on fire. Clouds raiſed by attraction, &c. from a ſea ſo circumſtanced, muſt needs contain more of the electric fire than clouds raiſed from the land, or a calm ſea; if, therefore, two clouds meet, fraught with unequal portions of this fluid, the cloud more electrified will depoſite its overplus in the cloud leſs electrified, and with a flaſh of lightning reſtore the equilibrium; and this fire rarefying the air, the adjoining air will ruſh in, and with a report called *thunder* reſtore the equilibrium of the air. If a cloud be attracted by a mountain, the electric fire will dart from the cloud to the mountain, and *vice verſa*.

Hence if a cloud replete with electric matter come too near a building, it will break upon the higheſt part of the building; as ſhewn by artificial clouds and thunder houſe.

Inflammable air may be fired by the electrical ſpark; which ſhews that if ſuch air be engendered by chalybeats, vitriolic acid, and water, fermenting in the bowels of the earth, and ſhould meet with this fluid in the earth, it would take fire, and blow up the earth in manner of an *earthquake*. In hot countries the electrical matter raiſed by attraction is returned in drops of rain; and as it may be proved by experiment that the elecerical fluid accelerates the motion of fluids, we ſhall from hence ſee the reaſon of ſuch large drops in hot countries, and in thunder ſhowers, as it is proved by experiment that hot bodies become conductor.

During the ſun's perihelion, which is in the winter months, the electric matter put in motion by the ſun's heat in the ſouthern hemiſphere, goes off to the cold regions of the northern hemiſphere, and is thrown off in a direction oppoſite to the ſun, into the upper parts of the atmoſphere, where it becomes viſible in appearance of an *aurora borealis*.

The ſenſitive plant is electrified by nature, as is alſo the *torpedo* and *electrical gymnotus*; but how they become ſo has not yet been determined by naturaliſts.

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LECTURES VII.

FORTIFICATION *and* MECHANICS.

THE firſt great warrior and conqueror of antiquity was Nimrod, the founder of the Babyloniſh empire, whoſe name in the Hebrew language ſignifies a rebel and apoſtate, and who perhaps derived the appelation from his cruel diſpoſition and tyrannical conduct. He began his reign in the year of the world 1757, and reigned 148 years: conſequently from his time fortification was invented; either to ſecure his uſurped authority over his fellow creatures, or by thoſe who were not of his party, to ſecure themſelves againſt his depredations, probably from both; for it is ſaid in the tenth chapter of Geneſis, that the beginning of his kingdom was Babel: and likewiſe that out of the ſame land went forth Aſhur, and built Nineveh, another ſtate for defence againſt the depredations of the firſt. Thus hoſtility was introduced, and fortification became an art of importance. A broad and deep ditch was dug, and on its inner bank great walls were built, with round towers at a bow-ſhot diſtance, that overlooked the country, and bid defiance to the enemy's battering ram. In proceſs of time ſquare towers, with the angles to the field took place of the round ones, and gave the firſt hint of the bullwark, now called a *baſtion:* but ſince the invention of gunpowder and artillery, it has required the united efforts of the mathematician and architect to evade its power; for the moderns can do greater execution with a ball of 6℔ weight, than the ancients could do with 600℔ weight.

A regular fortification is now ſhaped like a hexagon, with well adjuſted angles and ſides, and a baſtion at each corner, from which an enemy can be flanked in whatever direction he chuſes to approach; if he evade this, and attack the outermoſt angle of the baſtion, called the *ſalient angle*, his ſhot falls on an oblique wall, and rolls without much harm into the ditch: if he attack the *curtain* he has two baſtions playing upon him, as likewiſe the guns from the curtain: if he attempts to take the place by *ſtorm*, a broad and deep ditch, a wall ſix or eight yards high, the cannon and muſquetry oppoſe his paſſage; ſo that a fortification like this might have been deemed a ſufficient check to military phrenzy. But the curtain being found too weak to withſtand the vigorous attacks of an enemy, it was found neceſſary to cover thoſe with *out-works*, compoſed of angular walls called *ravellins*, pointing towards the fields; and where the country is open with a number of ſtrong works called *horn-works*, *crown-works*, *bonnets*, *lunettes*, &c. round all which run a large ditch,

and

and the *covert way*, defended by the *glacis*, a ſloping bank of earth next the field, and a *paliſado* of ſtrong pieces of wood. Theſe were ſo adjuſted, that two heights of cannon could play over the heads of the muſquetry on the covert way; and ſafe communications left between each under the works. The art has made no farther advances towards perfection; and ſuch is the diabolical nature of war in general, that every friend to human nature will hope that fortification may become uſeleſs, and that the time will come when the prophecy of Iſaiah will be verified; of which we have the following elegant paraphraſe by Mr. Pope:

No more ſhall nation againſt nation riſe,
Nor ardent warrior's meet with hateful eyes,
Nor fields with gleaming ſteel be cover'd o'er,
The brazen trumpets kindle rage no more;
But uſeleſs lances into ſcythes ſhall bend,
And the broad falchion in a plough ſhare end.

MECHANICS.

SIR ISAAC NEWTON's three laws of motion are the foundation of mechanics.

Law 1. EVERY body will continue in its ſtate of motion or reſt, except ſo far as it is compelled to change that ſtate by forces impreſſed. *

Law 2. THE change of motion is always proportional to the moving force impreſſed; and is always made according to that right in which that force is impreſſed. †

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* Proved by the *vis inertia* of matter.

† Proved by the ſquare and ball; which likewiſe demonſtrate the compoſition and reſolution of motion, ariſing from forces impreſſed in oblique directions.

Law 3. Action and reaction are always equal, and in contrary directions.

Whatever is inconſiſtent with theſe laws, is ſo with the general conſtitution of nature.

The *momentum*, or quantity of motion, ariſes from its quantity of matter, multiplied by its velocity.*

Every projectile is acted upon by two forces, *viz.* the *impetus* and *gravity*; by the firſt the body paſſes over equal ſpaces in equal times; and by the ſecond it deſcends through ſpaces which are as the ſquares of the times. And by theſe two forces conjointly, the body will not deſcribe a right line, but a curve called a *parabola*.

Bodies falling by the force of gravity, &c. are affected in the following manner:

I. They are equally accelerated.‖

II. The velocity is always proportional to the time of the fall.

III. The ſpaces paſſed through are as the ſquares of the times or velocity.

IV. The velocity is as the ſquare root deſcended through.

V. The ſpace paſſed through in the firſt ſecond is 16½ feet, nearly. †

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* Suppoſe two bodies, one of which ſtrikes an obſtacle with 2 parts of matter and 6 of velocity, and the other with 3 parts of matter and 4 of velocity; then $3\times4=12$, and $2\times6=12$; conſequently the ſmall body makes up with velocity what it wants in weight, and *vice verſa*.

‖ They move according to the odd numbers 1, 3, 5, 7, &c. for take the ſum of any number of terms, and it will be a ſquare number, as $1+3+5+7=16$, ſquare root is 4, for $16=4$.

† Suppoſe a heavy body upon the earth's ſurface whoſe centrifugal force is equal to its gravitating power, this body would move round the earth in 82 minutes of time; *viz.* it would move at the rate of 5 miles in a ſecond: the verſed ſine of that 5 miles will ſhew how far a heavy body deſcends in one ſecond, near the earth's ſurface, or how far it deſcends from a tangent. It has been demonſtrated by geometricians, that the verſed ſine of an arch may be found by ſquaring the chord, and dividing that product by the diameter of the circle. Thus 5 miles contain 26400 feet, whoſe

ſquare

A *pendulum* is any body ſuſpended upon, and moveable a point as a center: and the times of vibrations in different pendulums, are as the ſquare root of their lengths. Hence the lengths of pendulums are as the ſquares of the roots of their vibrations. The time of one vibration is to the time of deſcent through half the length, as the circumference of a circle to its diameter.§ Whence the length of a pendulum vibrating ſeconds will be found 39,2 inches nearly; and of an half ſecond 9,8 inches. An uniform ſtaff, &c. which is one-third part longer than a pendulum, will vibrate in the ſame time with it. This center of oſcillation is alſo the center of percuſſion, or that point in which the ſtroke is the greateſt poſſible.

The center of gravity of a body is a point round which all parts of the body balance each other: therefore, if this center is not ſupported the whole will fall. Hence bodies may be made to roll up, and be ſuſpended upon a point.

If two or more bodies in motion be connected together, they will have a common center of gravity between them; and the diſtance from the ſaid center will be reciprocally as the quantity of matter in each body.*

Circular

ſquare is 696960000, which divide by 42107149, the number of feet in the earth's diameter, and we get 16½ feet; and ſo far does a heavy body deſcend near the earth's ſurface in the firſt ſecond; which was proved experimentally by Sir Iſaac Newton.

§ As $3{,}1416^2 : 1^2 :: \overset{gra.}{193\frac{1}{2}} : 19{,}6$, half the length; then $19.6\times2=39{,}2$, the whole length; then as $4 : 1 :: 39{,}2 : 9{,}8$ half ſecond pendulum. By this inſtrument we can meaſure the diſtance of a cloud by numbering the ſeconds between the lightening and thunder. Suppoſe the time between ſeeing the flaſh and hearing the report is 10 ſeconds, then $10\times1142=11420$ feet diſtant.

By the pendulum we diſcover the force of gravity on divers parts of the earth's ſurface, and thence the true figure of the earth.

* The quantity of matter in the earth is 40 times more than in the moon, diſtance 60 ſemidiameters: ſo that the center of gravity between the earth and moon is near 2000 miles from the earth's ſurface.

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Circular motion and central forces are theſe: if a body be ſuſpended at the end of a ſtring, moveable about a center, and receive a blow in a horizontal poſition, it will be made to deſcribe a circle about the common center: while the motion continues the body will endeavour to fly off, which is called the centrifugal force. It acts upon the ſtring, and the ſtring draws it towards the center, whence it is called the *centripetal force*; and when we ſpeak of them indefinitely they are called *central forces.*[†]

If bodies of equal weight revolve in equal circles, with the ſame velocity, their centrifugal forces are equal.

If bodies of equal weight revolve in equal circles, with unequal velocities, their centrifugal forces are as the ſquares of the velocities.[‡]

If bodies of equal weight revolve in unequal circles, in ſuch a manner that the ſquares of their going round are as the cubes of their diſtance from the center of the circle they deſcribe, their centrifugal forces are inverſely as the ſquare of the diſtances from thoſe centers.[‖]

The Mechanical Powers are ſix in number; they are called mechanical becauſe they increaſe our power

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In like manner is the common center of gravity of the ſun, and all the planets which circulate about him, determined; if they were all placed in one right line, on one ſide of the ſun, then would the common center of gravity of the whole ſyſtem be diſtant from the ſun's ſurface $\frac{8}{10}$ of his ſemidiameter; and it is about this common center, and not about the ſun, that the planets and ſun itſelf revolve.

[†] By this kind of motion all the machinery of the planetary ſyſtem is performed. If, for the revolving body we ſubſtitute a planet; for the center we place the ſun; for the centripetal force, or ſtring, its power of attraction; and for the projectile force, the almighty power of God in the firſt creation of things.

[‡] This demonſtrates that a double velocity balances a quadruple power of attraction in the center.

[‖] This confirms that famous propoſition of Kepler; *viz.* 'That 'the ſquares of the periodic times of the planets are as the cube 'of the diſtance from the ſun; and that the ſun's attraction is in'verſely as the ſquare of the diſtance.'

n raiſing weights; *viz.* the *lever*, *pully*, *wheel* and *axle*, *inclined plane*, *wedge*, and *ſcrew*.

Rule for all mechanical powers.—There will be an equilibrium betwixt the weight and power, when they are to each other reciprocally as the diſtance from the center; *viz.* the weight multiplied into the diſtance is equal to the power multiplied into the diſtance of the *fulcrum* or *prop*.

Levers are of five kinds: 1. common ſort, where the prop is between the weight and power; 2. when the prop is at one end, the power applied at the other, and the weight between both; 3. when the prop is at one end, the weight at the other, and the power applied between both; 4. bended lever; 5. balance.

The *pulley*, if ſingle, has no mechanical advantage; but if two or more be combined, then the power is to the weight as one to the number of ropes that go to the lower block.

Wheel and axle.—The power is to the weight, as the diameter of the axle to the diameter of the wheel.

Inclined plane.—The power muſt be to the weight, as the weight of the plane is to the length.

Wedge.—The power will be to the reſiſtance, as the breadth of the wedge to both its ſides.

Screw.—The power is to the weight, as the height to the length of the thread.

The reaſon why the tides riſe at the ſame time on oppoſite ſides of the earth, and in oppoſite directions, is made plain by an experiment on the whirling table. The cauſe of their riſing on the ſide next the moon is owing to the moon's attraction; and on the oppoſite ſide, by the centrifugal force of the earth. The moon's attraction on the waters of the ocean is as 10, and the ſun's 3; ſo at the change of the moon the attraction of the ſun and moon conſpire together, and $10+3=13$, *viz.* with the force of 13, a *ſpring tide*; and the centrifugal force of the earth at the change being likewiſe 13, cauſes the tide on that ſide turned from the moon.

At the quarters the attraction of the ſun counteracts the attraction of the moon, *viz.* 10—3=7, a *neap tide.* At full moon the attraction of the ſun conſpires with the centrifugal force, and theſe two forces balance the moon's attraction; conſequently we have two tides every 25 hours: for the moon, at a mean rate, is near an hour later of ſouthing.

WIND is a current of air; and as air is a fluid, its natural ſtate is that of reſt: when this natural equilibrium happens to be deſtroyed in any part, there follows a motion of the air towards that part to reſtore it, and this motion of the air we call *wind.**

MANY are the cauſes that produce wind, but the moſt general are two; *viz. heat*, which by rarefying the air makes it lighter in ſome places than others; and *cold*, by condenſing it, makes it heavier: hence in the torrid zone the air being more rarefied, is much lighter than in other parts, and moſt of all over the equatorial parts of the earth.

Now by the earth's rotation eaſtward it follows, that thoſe parts of the air which lie on the weſt ſide of the point of greateſt rarefaction, and by flowing towards it, meet it, have leſs motion than thoſe parts on the eaſt of the ſaid point, which follow it; and therefore, the motion of the eaſtern air would prevail againſt that of the weſtern air, and ſo generate a continual eaſt wind, if this were all the effect of that rarefaction: but as the air is ſo greatly rarefied over the equator, and about the poles condenſed by cold, this heavier air from either pole is conſtantly flowing towards the equator, to reſtore the equilibrium deſtroyed by the rarefaction of the air over thoſe regions; hence a conſtant north and ſouth wind would be generated.

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* Hence, with reſpect to that place where the equilibrium of the air is diſturbed, we ſee the wind may blow from every point of the compaſs at the ſame time; thoſe who live northward have a north wind, and *vice verſa*; but thoſe who live on the ſpot where all theſe winds meet are oppreſed with whirlwinds and hurricanes, &c.

The velocity of the wind is various, from the rate of 1 to 50 or 60 miles per hour.

He gives the word, the bluſt'ring winds ariſe,
On billows billows mounted ſtorm the ſkies:
The foaming ſurges rage along the ſhores,
For help, in vain, the mariner implores;
Seas, urg'd by ſeas, with boundleſs fury roll,
And oceans oceans drive from pole to pole;
But at his nod the roaring tempeſts ceaſe,
And all the warring elements have peace;
Ocean, ſubmiſſive, ſmooths her furrow'd face,
And each ſubſiding wave finds its appointed place.

Now by compoſition of motion, theſe two directions of the air from eaſt and north, a conſtant N. E. wind will be generated in the northern hemiſphere; and a S. E. wind in the ſouthern hemiſpere, to a certain diſtance on each ſide of the equator, all round the earth: and this we find verified in the general *trade winds*, which conſtantly blow from N. E. and S. E. to about 30° of latitude on each ſide of the equator.

LECTURE VIII.

ASTRONOMY,

——— Hail Science heavenly born!
Thy ſchemes the life aſſiſt, the mind adorn.
Thy aid the Heaven's ſeal'd volumes wide impart;
And taught the ſeaman firſt his uſeful art;
Gave changing ſeaſons their determin'd ſpace,
And fix'd to hours and years their meaſur'd race.

AND God ſaid, '*Let there be* LIGHT;' and there was light. '*Let the* EARTH *be*;' and the earth was.

MOSES tells us, that '*In the beginning God created the* '*heavens and the earth, and the earth was ſhapeleſs and* '*void*;

'*void*; *darkneſs was upon the face of the deep, and the* '*Spirit of God moved upon the face of the waters.*'

From this text of the Jewiſh law-giver it follows, that the earth was a chaos, and muſt naturally put on the form of a globe; for it has been demonſtrated, that matter without a motion round its axis naturally puts on the form of a globe.

The Carteſians believed the earth was formed from atoms, without any creating power :* but if the earth was formed from atoms, the heavieſt would go towards the center, and the lighteſt would be upon the earth's ſurface, which is contrary to experience; ſo that the earth muſt be formed from ſome other cauſe.

It has been a matter of diſpute what was the figure of the earth; the ancients thought it was flatt; ſome the figure of a globe; others that of a prolate ſpheroid: but in order to prove what figure the earth was really of, the French king ſent mathematicians to the equator and polar circle, to meaſure a degree, and a degree was meaſured in France: from theſe meaſures, and the principles of gravitation, it was demonſtrated, that the earth is not a globe, but an oblate ſpheroid; that is, flatted towards the poles; for the equatorial diameter exceeds its polar by 35 miles. Now if the earth was partly fluid, as doubtleſs it was at its firſt formation, or when the Almighty gave it its projectile force, and as the centrifugal force is much greater at the equator than at the poles, the parts at the equator would fly off, and at the poles would contract, &c.

This oblate figure proves the diurnal motion; for if it was at reſt it would put on the form of a globe. We perceive not this motion, becauſe the air in which we live partakes of the ſame motion: likewiſe, when riding in a coach we appear to be at reſt, and the neighbouring country running by us; and in like manner we are deceived in the motion of the earth.

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* The Carteſians put glaſs bubbles in water, which they obſerved attracted one another, and ſo formed a body in the middle of the bowl; ſo they imagined the earth was formed from atoms in the like manner; but the real cauſe of their attraction is demonſtrated in lecture firſt.

Several people make an objection to the motion of the earth becauſe ſcripture mentions its ſtability; and likewiſe ſay, that if the earth turns round, the looſe bodies on its ſurface would fly off. But we muſt conſider, that the particles of which the earth is compoſed are held together by *the power of gravitation*: it is this power that gives weight to all bodies, or that tendency they have towards the center of the earth; for it exceeds the centrifugal force in proportion as 289 to 1. Hence the general top of the earth becomes its whole ſurface, and the general bottom its center: the *Antipodes* are therefore as much on the top as we.

When a ſhip approaches us at ſea we firſt ſee her *upper ſails*, then her *lower ſails*, and then the *hull*: by which it is evident ſhe moves on a round ſurface, or we ſhould ſee the whole at a time, &c. Several have ſailed round the earth; hence we conclude the earth is a globe. The earth's roundneſs is no more affected by the largeſt mountains, than the roundneſs of a common globe is by a few grains of duſt thrown upon it.

The moſt celebrated Hypotheſes, or ſyſtems of the world, are three; *viz.* 1. the *Ptolomaic*, invented by Ptolomy: 2. the *Tychonic* Syſtem, invented by Tycho Brahe: 3. the *Copernican*, or ſolar ſyſtem, invented by Pythagoras, revived by Copernicus, and demonſtrated by Sir Iſaac Newton.

Ptolomy ſuppoſed the earth fixed immoveably in the center of the univerſe, and that the ſeven planets, conſidering the moon as one of the primaries, were placed near to it; above them was the firmament of fixed ſtars, then the chryſtaline orbs, then the *primum mobile*, and laſt of all, the *cœlum empyrium*, or heaven of heavens. All theſe vaſt orbs he ſuppoſed to move round the earth once in 24 hours; and, beſides that, in certain ſtated or periodical times.

TYCHO ſuppoſed the earth to be the center of the ſtars, and of the ſun and moon; but made the ſun the center of the planetary motions. Thus the ſun, with all the planets, was made to revolve about the earth once a year, to account for the annual motion; and the earth round its axis, from weſt to eaſt, once in 24 hours, to account for the diurnal motion.

THE COPERNICAN, or true ſyſtem of the world, is demonſtrated upon the principles of *compoſition* and *reſolution of motion*, *projectile* and *centrifugal forces*, &c. (ſee Mechanics.)

THE bodies that compoſe the ſolar ſyſtem are about 48; *viz.* 8 primary, 10 ſecondary, and 30 comets.

SUN—an immenſe globe of fire, is placed in the center, or rather in the lower focus, of all the planets and comets, and by various agitations of the planets, turns round on his axis in 25¼ days: his diameter is computed to be above 800000 miles, conſequently the ſun is 1000000 times as large as the earth.*

MERCURY is computed to be 32 millions of miles from the ſun; and by moving at the rate of 95000 miles every hour in his orbit, he revolves round the ſun in about 88 of our days. His diameter is 2600 miles, conſequently the earth is 36 times as large. The light and heat is ſeven times as great as upon the earth. His elongation never exceeds 21°, conſequently his days and nights have not been determined by aſtronomers, on account of his nearneſs to the ſun. †

VENUS

* *Along the ſkies the* SUN *obliquely rolls,*
Forſakes by turns, and viſits both the poles;
Diff'rent his track, but conſtant his career;
Divides the times, and meaſures out the year:
To climes returns where freezing winter reigns,
Unbinds the glebe, and fructifies the plains:
The crackling ice diſſolves, the rivers flow;
Vines crown the mountains tops, and corn the vales below.

† *Firſt* MERCURY, *amidſt full tides of light,*
Rolls next the Sun, in his ſmall circle bright.

All

Venus, the next planet in the ſyſtem, known by her brilliancy, is about 59 millions of miles from the ſun; and by travelling at the rate of 69000 miles every hour in her orbit, moves round the ſun in 225 of our days.

By the obſervations of Bianchini it appears that Venus turns round her axis in 24¼ days, ſo that there are but 9¼ days in Venus's year and every fourth year is a leap year, as in the earth: ſhe is near as big as the earth, and her diurnal motion is 43 miles in an hour. Her light and heat are twice as great as the light and heat received by the earth. Venus's greateſt elongation is about 47°, and inclines 75° to the axis of her orbit, which is 51° more than the axis of the earth inclines; conſequently her polar circles are within 15° of her equator, and her tropics are within 15° of her poles; therefore her ſeaſons vary very faſt, the ſun paſſing over more of her in one day than over the earth in a quarter of a year; hence the heated places have time to cool. Her ſeaſons are, a ſpring and autumn, a ſummer as long as both, and a winter as long as the whole.*

The

All that dwell there muſt be refin'd and pure;
Bodies like ours ſuch ardour can't endure.
Our Earth would blaze beneath ſo fierce a ray,
And all its marble mountains melt away.
Baker's Univerſe.

* *Fair* VENUS *next fulfils her larger round,*
With ſofter beams, and milder glory crown'd;
Friend to mankind, ſhe glitters from afar,
Now the bright Ev'ning, now the Morning ſtar.
Baker's Univerſe.

The greateſt diſtance of the earth, or any planet, from the ſun, is called the *aphelion*; its leaſt diſtance is called the *perihelion*.

A planet is ſaid to be in *conjunction* with the ſun when its apparent place, ſeen from the earth, is in or near the ſun's place: it is ſaid to be in *oppoſition* when the earth is between the ſun and the planet.

The *elongation* of a planet is its apparent diſtance from the ſun, as ſeen from the earth. A planet has no elongation when in conjunction with the ſun; in oppoſition it has 180°. An inferior planet

THE *Earth* is the next planet in the ſyſtem, computed to be 82 millions of miles from the ſun; and, by moving at the rate of 58000 miles every hour in its orbit, moves round the ſun in one year. The diurnal motion is 1040 miles in an hour in the equator, but in the latitude of 54° only 560 miles. †

THE *Moon* is 240000 miles diſtant from the earth, and moves from one fixed ſtar to the ſame again in 27 days, 7 hours, and 43′; but from change to change in 29 days, 12 hours, and 44′, and turns round its axis in the ſame time it turns round the earth, ſo that it always turns the ſame face to the earth.

MARS, the next planet in the ſyſtem, at the diſtance of 125 millions of miles from the ſun; and by moving at the rate of 47000 miles every hour in his orbit, performs his circuit round the ſun in 687 days. He turns round his axis in 24 hours and 40 minutes; and his diameter is 4444 miles, ſo that he is but one-ſixth part

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planet may be in conjunction with the ſun in two ſituations; 1. when it is between the earth and the ſun, called the inferior conjunction; 2. when the ſun is between the earth and planet called its ſuperior conjunction; but it can never be in oppoſition to the ſun.

When the inferior planets are at their greateſt elongation they appear ſtationary, or continue in the ſame place for ſome time, before their motion changes from direct to retrogade, or from retrograde to direct again.

The time of the retrogreſſion of Venus is about 40 days; of Mercury 18 days.

As Venus moves from her ſuperior to her inferior conjunction, ſhe ſets after the ſun, and is called an *evening ſtar*; and as ſhe is moving from her inferior to her ſuperior conjunction, ſhe riſes before the ſun, and is called the *morning ſtar*. When Venus is an evening ſtar her horns are turned towards the weſt, and *vice verſa*. Venus is an evening and morning ſtar 290 days alternately, which is owing to the earth's motion in the ecliptic.

† *More diſtant ſtill, our earth comes rolling on,*
And forms a wider circle round the ſun,
With her the Moon, companion ever dear!
Her courſe attending thro' the ſhining year.
Baker's Univerſe.

as large as the earth. The light and heat received by this planet from the ſun, is but equal to one half of the light and heat received by the earth. He has no variety of ſeaſons.*

JUPITER, the largeſt planet in the ſyſtem, and next in order, is at five times the diſtance from the ſun that the earth is, and ſo enjoys only a twenty-fifth part of the light and heat. He moves at the rate of 25000 miles in an hour, and performs his courſe round the ſun in 11 years and 315 days. He turns round his axis in 9 hours and 56 minutes: his hourly diurnal motion exceeds his motion in the ecliptic by 920 miles, and by this quick rotation on his axis, his equatorial diameter exceeds his polar in proportion as 13 to 12, ſo that his poles are 3000 miles nearer his center than his equator. The ſwiftneſs of his diurnal motion draws the clouds upon his ſurface into ſtreaks or lines called BELTS.‖

JUPITER

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* *Next* MARS: *alone runs his appointed race,*
And meaſures out, exact his deſtin'd ſpace;
Nor nearer does he run, nor farther ſtray,
But finds the point from whence he roll'd away.

The apparent motions of the ſuperior planets agree in many reſpects with thoſe of the inferior ones, which have been already explained.

The ſuperior planets are ſometimes in conjunction with the ſun, ſometimes in quadrature, and ſometimes in oppoſition.

When a ſuperior planet is moving from one of its apparent ſtations through its conjunction, its geocentric motion is direct; but through the oppoſition its geocentric motion is retrograde.

The time of the retrogreſſion of Mars is about 3 Months; of Jupiter 4 months, and of Saturn 4½ months.

‖ *Yet more remote from day's all-cheering ſource,*
Large JUPITER *performs his conſtant courſe;*
Four friendly Moons with borrow'd luſtre riſe,
Beſtow their beams benign, and light his ſkies.

The planets viewed through a teleſcope appear ſtripped of their adventitious rays, and appear like circular planes of a determined magnitude, whoſe diameters may be meaſured by a micrometer.

The

JUPITER has four moons or ſatellites moving round him, at the diſtance and periods as under:

	MILES DIST.		D.	H.	M.
I.	229000	— in —	1	18	36
II.	364000	— in —	3	13	15
III.	580000	— in —	7	3	59
IV.	1000000	— in —	16	18	30

SATURN, the next in order, is 600 times as large as the earth; his diſtance from the ſun is computed to be 780 millions of miles, and by moving at the rate of 18000 miles every hour in his orbit, moves round the ſun in 29 years and 167 days. On account of the great diſtance of this planet, aſtronomers have not been able to determine the length of his days and nights. The light and heat received by this planet is but the one-ninetieth part of the light and heat received by the earth; but to make amends, he is attended by five moons, beſides a broad luminous ring, which reflects the light ſtrongly upon him. The ring is inclined about 30° to the plane of the ecliptic; its diſtance from the body of the planet is about 21000 miles, which is the breadth of the ring. †

The Satellites of Jupiter, &c. caſt a ſhadow upon their primaries, which may be obſerved by a teleſcope, and ſeen to paſs over the disc of the planet like a ſpot. From hence the longitude of places upon the earth may be determined, as likewiſe the velocity of light.

† *Fartheſt and laſt, ſcarce warm'd by Phœbus' ray,*
Through his wide orbit, SATURN *wheels away.*
How great the change, could we be wafted there!
How ſlow the ſeaſons! and how long the year!
One Moon on us reflects her chearful light,
There five attendants brighten up the night:
Here the blue firmament bedecked with ſtars;
There, overhead, a lucid arch appears.
From hence, how large, how ſtrong the Sun's bright ball!
But, ſeen from thence, how languid and how ſmall!
When the keen North with all its fury blows,
Congeals the floods, and forms the fleecy ſnows,

The *Georgium Sidus* is a planet newly diſcovered by Mr. Herſchell. It moves about the thirtieth part of a degree in 24 hours; is near twice as far diſtant from the ſun as Saturn, and will be near 82 years and ſix months in going round him. It is 100 times as large as the earth.*

The *Parallax* of the heavenly bodies is the change of their apparent places, when viewed at different ſtations, as at the center and ſurface of the earth: its uſe is to find the diſtance of the heavenly bodies.

The *greater Circles of the Sphere* are ſix in number; *viz.* 1. the Equinoctial, which divides the ſphere into two parts: 2. the ecliptic, or line in which the ſun apparently moves: 3. the Meridian, which paſſes through both poles: 4. the Horizon: 5. and 6. the two Colures.

The *leſſer Circles of the Sphere* are four in number; *viz.* the two Tropics, and the two polar Circles.

'Tis heat intenſe to what can there be known,
Warmer our Poles than is its burning Zone.
Who there inhabit muſt have other powers,
Juices, and veins, and ſenſe, and life, than ours;
One moment's cold, like theirs, would pierce the bone,
Freeze the heart's blood, and turn us all to ſtone.—
Strange and amazing muſt the diff'rence be
'Twixt this dull planet and bright Mercury;
Yet reaſon ſays, nor can we doubt at all,
Millions of beings dwell on either ball,
With conſtitutions fitted to that ſpot,
Where Providence, all-wiſe, has fix'd their lot.

Baker's Univerſe.

The Periods and Diſtances of Saturn's Satellites.

	PERIODS,			DISTANCE.
	D.	H.	M.	
I.	1	21	19,	and is 140000 miles from his center.
II,	2	17	40,	—— 187000 —— ——
III.	4	12	25,	—— 263000 —— ——
IV.	15	22	41,	—— 600000 —— ——
V.	79	7	48,	—— 1800000 —— ——

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* This planet has only ¼ as much light and heat as Saturn.

Now as the ſun always enlightens one half of the earth's ſurface, the circle which terminates the enlightened and darkened hemiſpheres is called *The Circle of Illumination*; and as the ſun revolves round its axis from weſt to eaſt, the ſucceſſion of day and night becomes evident; and as the earth moves in the ecliptic with its axis inclined 23½°, and moving parallel to itſelf, turns both poles alternately to the ſun, which cauſes the different ſeaſons, as is ſhewn by experiment.

The ſummer is eight days longer than the winter: this is owing to the earth's moving in an eliptic orbit; for it is at its perihelion in winter, and ſo moves faſter.

The *Moon* moves round the earth, &c. in 27 days, 7 hours, and 43 minutes, at the diſtance of 240000 miles: her diameter is 2180 miles, and ſhe moves at the rate of 2290 miles every hour. Her orbit is inclined to the ecliptic in an angle of 5⅓°: the points where it interſects the ecliptic are called *moon's nodes*; theſe nodes have a ſlow retrograde motion of 19⅓° in a year, which carries them round the ecliptic, contrary to the order of the ſigns, in 18 years and 225 days. We do not ſee the moon at the conjunction; but at the oppoſition her whole face. After the new moon her horns are turned towards the eaſt, and before new moon towards the weſt; which proves that ſhe ſhines by a borrowed light from the ſun.

An *Eclipſe* is a deficiency of light in the heavenly bodies. In an eclipſe of the ſun its light is intercepted from the ſight by the moon's paſſing between the ſun and earth. An eclipſe of the moon is cauſed by her paſſing through the ſhadow of the earth, whereby ſhe is deprived of the ſun's light. The ſun can never be eclipſed but at the new moon; neither can there be an eclipſe of the moon but at the time of the full moon. In the firſt caſe the new moon muſt be within 18 degrees, in the laſt within 12 degrees, of one of the nodes.

If theſe nodes kept always in the ſame ſign of the ecliptic, the ſun and moon would always be eclipſed in the ſame places, and at the ſame time every year; but as the nodes have a regreſſive motion of 19⅓ degrees in one year, and as the other meet the nodes, we ſhall have a reſtitution of the ſame eclipſe in 18 [illegible] years, 10 or 11 days, according as four or five leap years intervene.

A *Comet* is a kind of planet which revolves round the ſun in a very eccentric orbit, and recedes farther from the ſun in its aphelion than any of the planets. It is inviſible until it comes to the planetary regions, and then appears ſurrounded with a denſe atmoſphere. From the ſide oppoſite the ſun it emits a ſhining tail, ſhort at firſt, but increaſing as the comet approaches the ſun; and after its perihelion the tail is longeſt and moſt luminous. The matter of which the tail conſiſts is ſuppoſed to be the electric matter collected by the comet in its aphelion, which being put in motion by heat is diſperſed through the planetary regions.*

Electric Matter, Aurora Borealis, and Comets' Tails, are ſuppoſed to be ſubſtances of the ſame nature, for the rays of light ſuffer no refraction in paſſing through them.

The *fixed ſtars* are ſuppoſed to be ſuns, with ſyſtems of worlds moving round them, as the planets move round the ſun; for whoever ſuppoſes them placed in one concave ſphere, as they appear to be, muſt have a very contracted notion of the all-wiſe creator. The reaſon of one ſtar appearing ſo great and and another ſo ſmall, is, that one is near us in compariſon of the other; for by obſervations of Dr. Bradley, the neareſt fixed ſtar is 400000 times farther from us than we are from the ſun.[||] Their diſtance is ſo great, that a cannon ball would be 7000000 millions of years in flying to the neareſt of them, with the ſame velocity as it goes from the mouth of a cannon: hence the ſun's light could never reach the fixed ſtars, and be reflected back with ſuch luſtre; which proves that they ſhine with their own native light. There are but 1000 ſtars viſible to the naked eye in both hemiſpheres, but by uſing glaſſes we diſcover more, and the better our glaſſes are, the more ſtars may be obſerved. Mr. Herſchell has diſcovered 30000 ſtars, and doubtleſs many are yet undiſcovered, or that no glaſs can be made to magnify ſo as

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* *At his command, affrighting human kind,*
Comets drag on their blazing length behind.
Nor, as we think, do they at random rove,
But in determin'd times, through long elipſes move.
And tho' ſometimes they near approach the ſun,
Sometimes beyond our ſyſtem's orbit run,
Throughout their race they act their maker's will,
His power declare, his purpoſes fulfil.

Baker's Univerſe.

[||] *Come forth, O man, yon azure round ſurvey,*
And view thoſe lamps which yield eternal day:
Bring forth thy glaſſes; clear thy wond'ring eyes;
Millions beyond the former millions riſe:
Look farther:—millions more blaze from remoter ſkies.

And canſt thou think, poor worm! thoſe orbs of light,
In ſize immenſe, in number infinite,
Were made for thee alone, to twinkle to thy ſight.
Preſumptuous mortal! can thy nerves deſcry
How far from thee they roll, from thee how high;
With all thy boaſted knowledge canſt thou ſee
Their various beauty, order, harmony.

Correct thy aukward pride, be wiſe, and know
Thoſe glitt'ring ſpecks thou ſcarce diſcern'ſt below,
Are founts of day, ſtupendous orbs of light,
Thus by their diſtance leſſen'd to thy ſight.

Now, if thou canſt, the mighty thought ſuſtain,
If it not akes thy ſoul, and racks thy brain,
Conceive each ſtar thou ſeeſt another ſun,
In bulk, and form, and ſubſtance like thine own.

Conſult with reaſon, reaſon will reply,
Each lucid point which glows in yonder ſky
Informs a ſyſtem in the boundleſs ſpace,
And fills with glory its appointed place;
With beams unborrow'd brightens other ſkies,
And worlds, to thee unknown, with heat and life ſupplies.

Baker's Univerſe.

to make them viſible. Some ſtars appear double, and others of different colours; our polar ſtar is double. Some change their magnitude, as is the caſe with the ſtar Algol, in Meduſa's Head, which riſes from a ſtar of the third magnitude to one of the ſecond in 2 days and 21 hours. By analogy we may conclude, that at a proper diſtance our ſun would dwindle into a fixed ſtar, and all its ſyſtems of worlds diſappear: conſequently we may ſuppoſe that every fixed ſtar is a ſun, giving light, heat, and vegetation to ſyſtems of worlds moving round them; for nature does nothing in vain; and as the microſcope diſcovers every drop of water, every blade of graſs, &c. ſwarming with inhabitants, we muſt ſuppoſe all other parts of the univerſe ſtored with inhabitants, though our glaſſes cannot diſcover them.*

The Heavens declare the glory of God, and the Firmament ſheweth his Handy-work.

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* *Heed well this orb, where fate has fix'd thy lot,*
Seeſt thou one uſeleſs, or one empty ſpot;
Obſerve the air, the waters, and the earth,
Each moment gives ten thouſand creatures birth.
Here ev'ry place, ſo far from lying waſte,
With life is crouded, and with beauty grac'd:
Nor can thoſe other worlds, unknown by thee,
Leſs ſtor'd with creatures, or with beauty be;
For God is uniform in all his ways,
And every where his boundleſs pow'r diſplays;
His goodneſs fills immeaſureable ſpace,
Reſtrain'd by time, nor limited to place;
His wiſdom form'd great nature's mighty frame,
And rules by laws eternally the ſame. BAKER.

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EXPLANATION

OF THE TECHNICAL TERMS USED IN THIS WORK.

ABBERATION, *wandering.*
Abſorb, *to ſuck up.*
Æolopyle, *an hydraulic inſtrument for converting water into an elaſtic ſteam.*
Accretion, *the act of growing together.*
Aerial, *belonging to the air.*
Air-pump, *a machine to draw air out of veſſels.*
Alkali, *a ſubſtance which when mixed with an acid produces fermentation,*
Altitude, *height.*
Amalgama, *a mixture of metals.*
Amphiſcii, *inhabitants of the torrid zone*
Angle, *a point where two lines meet.*
Animalcula, *a little animal.*
Anomaly, *irregularity.*
Antarctic, *relating to the ſouth pole.*
Antipodes, *people who live on oppoſite ſides of the globe, and who have their feet oppoſite to ours.*
Antocci, *inhabitants of the earth who live under the ſame meridian, but oppoſite parallels.*
Apex, *the top or point of any thing.*
Aphelion, *that point of a planet's orbit in which it is at its greateſt diſtance from the ſun.*
Apogee, *the point of the ſun's &c. orbit when fartheſt from the earth.*
Arctic, *the northern pole.*
Armillary, *reſembling a ring.*
Aſcii, *inhabitants of the torrid zone.*
Atmoſphere, *the ſurrounding air.*
Atom, *a ſmall particle of matter.*
Attraction, *the power of drawing to.*
Attrition, *act of rubbing.*
Aurora Borealis, *ſtreamers, northern lights.*
Axis, *the line on which any thing turns.*
Barometer, *a weather glaſs.*
Baſtion, *a bulwark or fortreſs.*
Burning-glaſs, *a glaſs that collects the ſun's rays into a focus.*
Camera Obſcura, *an optical machine.*
Capillary, *reſembling ſmall hairs.*
Cardinal, *principal.*
Catoptrics, *that part of optics which treats of viſion by reflection.*
Centrifugal, *flying from the center.*
Centripetal, *tending to the center.*
Chaos, *confuſion, indigeſted heap.*
Chronology, *the ſcience of computing*
Circulation, *a courſe of motion tending to the ſame point from which it began.*
Circumference, *the line including any thing.*
Circumvallation, *ſurrounding with walls.*
Citadel, *a caſtle, a fortreſs.*
Coagulate, *run into lumps.*
Coheſive, *the power to ſtick together.*
Colures, *circles paſſing thro' both poles, and the equinoctial and ſolſtitial points.*
Comet, *a blazing ſtar.*
Concave, *hollow.*
Condenſe, *cloſe, thick.*
Conical, *in form of a cone.*
Conſtellation, *a cluſter of fixed ſtars.*
Converge, *tending to a point.*
Convex, *riſing like the outſide of a globe.*
Cornea, *horney.*
Corpuſcle, *a ſmall body, an atom.*
Crepuſculum, *twilight.*
Chryſtaline, *like to chryſtal in brightneſs.*
Culminate, *to be in the meridian.*
Curve, *any thing bent.*
Cycle, *a round of time.*
Cylinder, *a long, round body.*
Declination, *the act of bending.*
Decompoſition, *compounded again.*
Degree, *the 360th part of a circle, on the earth 60 miles.*
Denſe, *compact, cloſe.*
Diagonal, *from angle to angle.*
Diameter, *a line which paſſes through the center of a circle, and divides it into two parts.*
Digit, *twelfth part of the diameter of the ſun or moon.*
Dioptrics, *ſcience of refracted viſion.*
Disc, *the face of the ſun.*
Diverge, *to bend from one point.*
Diviſibility, *quality of admitting diviſion*
Diurnal, *daily.*
Ebullition, *boiling up.*
Excentrically, *deviating from the center.*
Eclipſe, *obſcuration of a luminary.*
Ecliptic, *a line on the ſpheres of the world, which the ſun appears to deſcribe in its annual revolution.*
Effluvia, *ſmall particles flying off from bodies.*
Elaſticity, *ſpring or force of bodies.*
Electricity, *attraction without magnetiſm.*
Elipſe, *an oval figure.*
Elongation, *act of lengthening.*
Embraſures, *openings in a wall.*
Emerſion, *reappearance of a ſtar.*
Enfilade, *a ſtrait paſſage.*
Equation, *equality, or making even.*

Equator, *a line dividing the globe in two parts, north and ſouth.*
Equilibrium, *equality of weight.*
Equinox, *equal day and night.*
Eudiometer, *an inſtrument to meaſure the purity of the air.*
Falcated, *bent like a ſcythe.*
Flaccid, *limber, lax.*
Focus, *fire-place, likewiſe the point of convergence where all the rays meet.*
Gibbous, *crooked.*
Hemiſphere, *half the globe.*
Heteroſcii, *inhabitants of the temperate zones, their ſhadows fall one way.*
Hexagon, *a figure of ſix ſides.*
Horizon, *the line that terminates the ſight.*
Humidity, *power of wetting, moiſture.*
Hydraulics, *the art of conveying water.*
Hydrometer, *an inſtrument to meaſure the extent of water.*
Hydroſtatics, *ſcience of weighing fluids.*
Hypotheſis, *a ſyſtem upon ſuppoſition.*
Impetus, *a violent effort.*
Incidence, *falling upon.*
Inſulated, *a conducting body ſeparated from another by a non conductor, as an iſland is ſeparated from the main land by water.*
Lens, *a glaſs convex on both ſides.*
Longitude, *from eaſt to weſt, length.*
Mechanics, *the geometry of motion.*
Medium, *any thing intervening.*
Meridian, *line dividing the world.*
Monſoons, *trade winds.*
Nadir, *point oppoſite to the zenith.*
Negative, *contrary to affirmative.*
Nodes, *the point of interſection of two orbits.*
Nonageſimal degree, *the 90th degree, or higheſt point in the ecliptic.*
Oblate, *flatted at the poles.*
Oblique, *not ſtreight, crooked.*
Occultation, *a hiding.*
Oppoſition, *an aſpect,* 180° *diſtant.*
Orb, *a hollow ſphere*
Oſcillation, *the act of moving back and forwards like a pendulum.*
Parallax, *the diſtance between the true and apparent place of a ſtar.*
Parallel, *a line at the ſame diſtance from another.*
Pellucid, *bright, tranſparent.*
Penumbra, *an imperfect ſhadow.*
Perigee, *place of a planet when neareſt the earth.*
Perihelion, *place of a planet when neareſt the ſun.*
Perioeci, *inhabitants of the earth who live under the ſame parallels, but oppoſite ſemicircles of the meridian.*
Periſcii, *inhabitants of the frigid zones.*
Perpendicular, *a line at right angles to another.*
Phaſes, *appearances.*
Phænomenon, *a wonderful appearance.*
Pole, *extremity of the earth.*
Preceſſion, *advancing.*
Projectile, *a body put in motion.*
Prolate, *egg-ſhaped.*
Quadratures of the moon, *are the medial points of her orbit.*
Radius, *the ſemidiameter of a circle.*
Ratio, *proportion.*
Ravelin, *a half moon in fortification.*
Recipient, *receiver.*
Reflection, *directed backwards.*
Refraction, *a variation of a ray of light*
Refrangible, *turned out of courſe.*
Repulſion, *driving off from itſelf.*
Reſervoir, *a large conſervatory of water*
Retrograde, *to go backwards.*
Revolution, *returning motion.*
Rotation, *turning round as a wheel.*
Segment, *part of circle.*
Solar, *belonging to the ſun.*
Solſtice, *ſtation of the ſun.*
Sphere, *a globe.*
Spheriod, *an oblong body.*
Teleſcope, *a glaſs for diſtant views.*
Terraqueous, *earth and water.*
Torrid, *burning, hot.*
Tranſparent, *pervious to the light.*
Vacuum, *ſpace unoccupied by matter.*
Vapours, *to fly off in fumes.*
Vertex, *top of any thing.*
Vegetation, *growing like plants.*
Vitreous, *reſembling glaſs.*
Vortex, *any thing whirled round.*
Zenith, *the point over head.*
Zodiac, *the ſun's track in the 12 ſigns.*
Zone, *a diviſſion of the earth.*

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FINIS.